VOLUME 66, NUMBER 1 JANUARY–MARCH 2019

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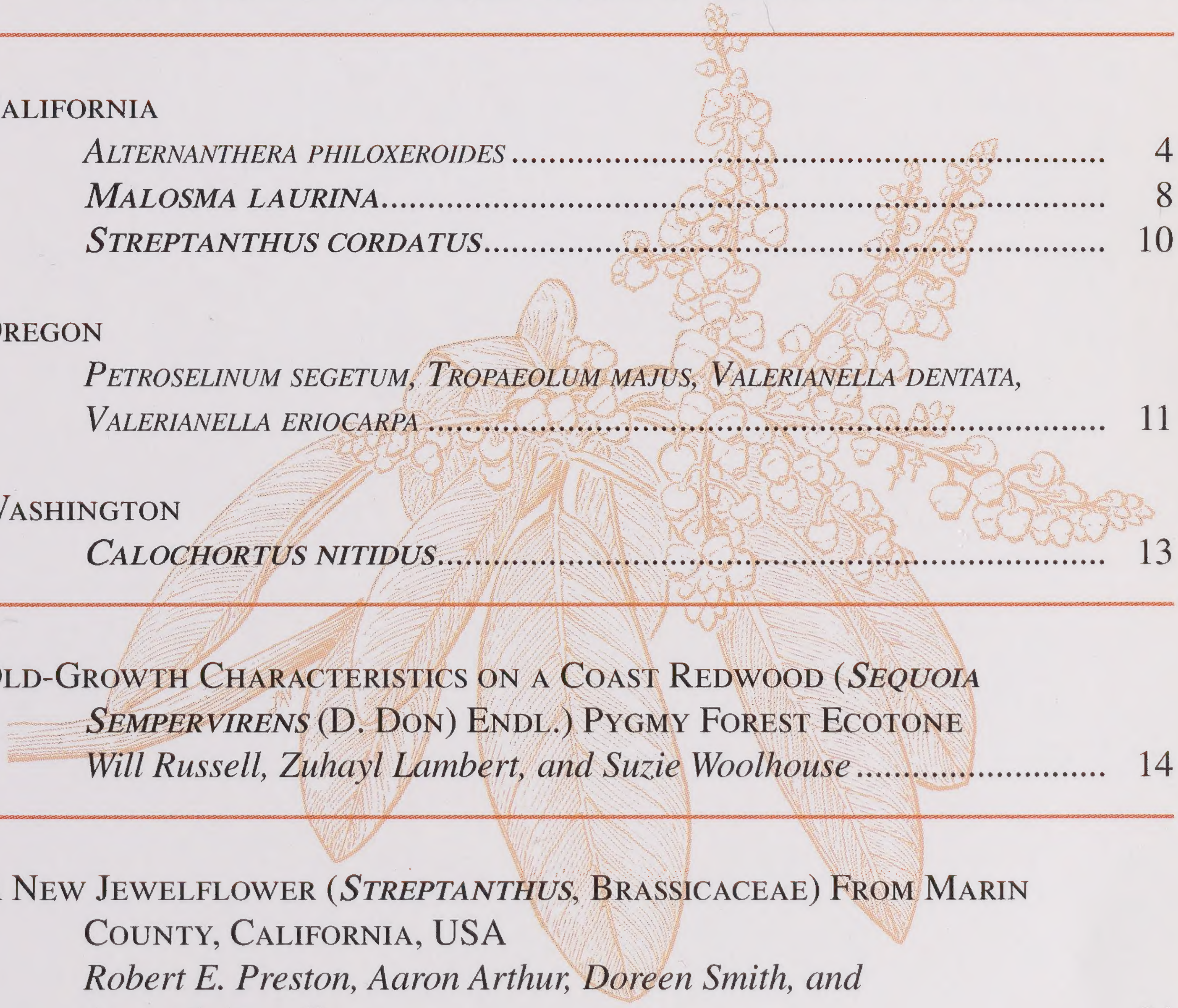
MADROÑO

A WEST AMERICAN JOURNAL OF BOTANY



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PUBLISHED QUARTERLY BY THE CALIFORNIA BOTANICAL SOCIETY

MADROÑO (ISSN 0024-9637) is published quarterly by the California Botanical Society, Inc., and is issued from the office of the Society, c/o Jepson Herbarium, 1001 Valley Life Sciences Building, University of California, Berkeley, CA 94720-2465. Subscription information is on inside back cover. Established 1916. Periodicals postage paid at Berkeley, CA, and additional mailing offices. Return requested. Postmaster: Send address changes to Madroño, Rachael L. Olliff Yang, Membership Chair, c/o Jepson Herbarium, 1001 Valley Life Sciences Building, University of California, Berkeley, CA 94720-2465. membership@calbotsoc.org.

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MADROÑO, Vol. 66, No. 1, pp. 1–3, 2019

DEDICATION TO JESSICA MAE OROZCO

Volume 66 of Madroño is dedicated to Jessica Mae Orozco, a skilled field biologist and passionate ethnobotanist with a commitment to preserve Native American botanical knowledge (Fig. 1). In a tragically short amount of time, she was able to accomplish so much and make a lasting impression on the botanical community before her life was cut short, when she was shot and killed on October 27, 2018, at the age of 31.

She was born in Sacramento, CA, where she attended and worked as a Teaching Assistant at American River College. In 2010, she transferred to San Francisco State University (SFSU), where she earned a B.S. in Botany with a minor in American Indian Studies. At SFSU, Jessica was present in mind and body in every class and on every field trip. She always maintained a positive attitude with an infectious enthusiasm. She was a favorite of everyone. No hurdle was too high for her, no climb too difficult, and as she accomplished more, she would celebrate with a smile and a laugh

FIG. 1. Jessica proudly demonstrating a Nolina inflorescence. Her love of plants was effusive and one of her greatest joys was sharing her knowledge of plants with others. Photo Credit: Jessica Orozco Facebook Page.

If you knew Jessica, or if you follow her on Facebook, Instagram (@plantsnotpantz), or read her blog (https://jessicaorozco.wordpress.com), you will often read the phrase "PLANTS NOT PANTS!!" Jessica coined this cheer while on a field trip while taking Plant Taxonomy at SFSU. While visiting the southern desert over spring break, the phrase stemmed from a plant keying session in a large tent on a cold night. It quickly became a class motto. Jessica was the 2012 academic hood nominee for the SFSU Biology Department and gave a moving speech at the biology graduation ceremony. Being the spirited botanist that she had become, she ended her speech with a triumphant, "Plants not Pants!" followed by cheers from the fellow botany students in the crowd.

As an undergraduate, Jessica participated in two National Science Foundation Research Experience for Undergraduates (REU) programs, both studying plant biology: one at the Boyce Thompson Institute for Plant Research at Cornell University (Summer 2010), and the other at Blandy Experimental Farm in Boyce, Virginia (Summer 2011) (Fig. 2). During her time at SFSU, she also worked with student groups doing indigenous plant restoration at Indian Canyon - one of her favorite places in all of California. Prior to beginning graduate studies, she spent time at the UC Berkeley Jepson Herbarium, learning research techniques. Even during her undergraduate education, Jessica was already making meaningful connections with botanists and members of native communities across California and the country.

She went on to earn her Master's degree in Botany from Claremont Graduate University at the Rancho Santa Ana Botanic Garden (RSABG), during which time she was awarded a Ford Foundation Fellowship. Jessica's M.S. thesis was a floristic study of the South Fork of the Tule

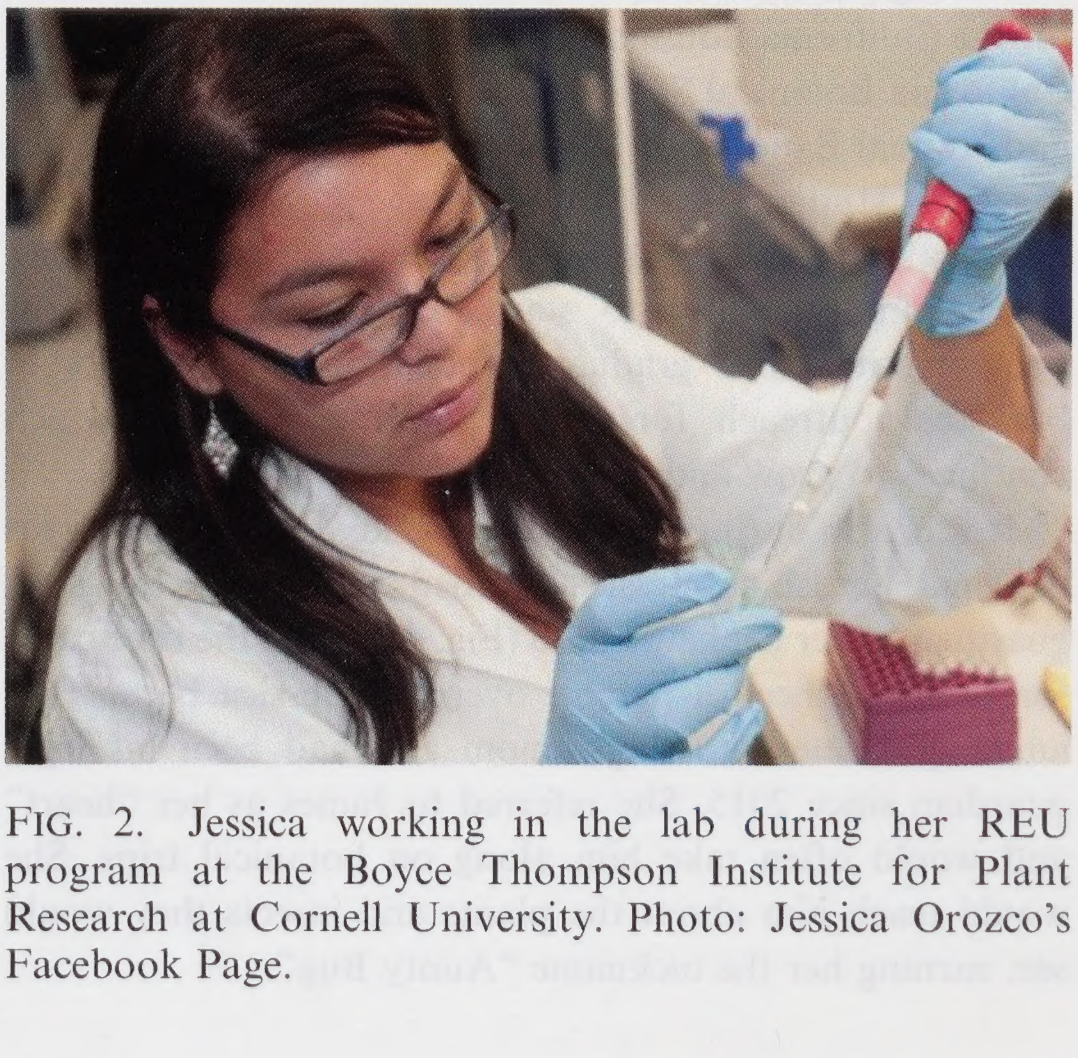

FIG. 2. Jessica working in the lab during her REU program at the Boyce Thompson Institute for Plant Research at Cornell University. Photo: Jessica Orozco's Facebook Page.

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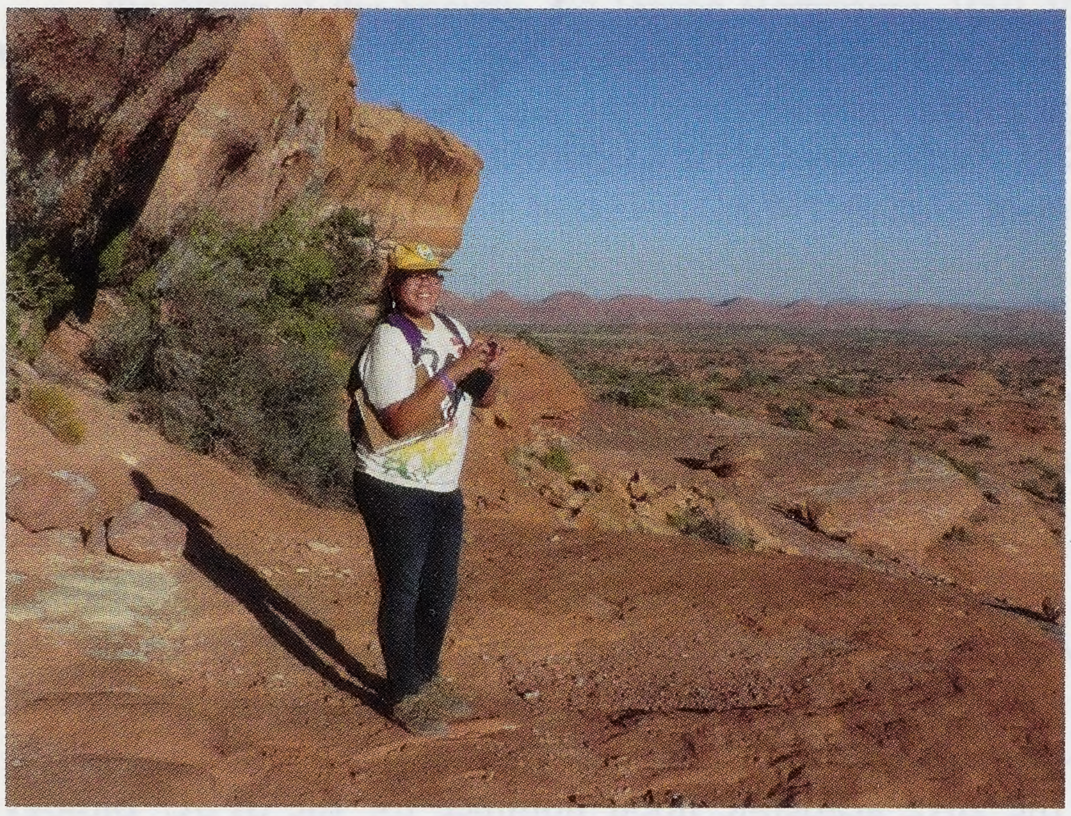

FIG. 3. Jessica Orozco at the "Twist" in southeastern Utah, September 2014 during her studies with Arnold Clifford. He recalled how happy she was this day, knowing she was in the region where Alice Eastwood collected plant specimens in the 1890's. Photo Credit: Arnold Clifford.

FIG. 4. Jessica and her beloved nephew, James Kitchens, at a wedding, displaying her botanical tattoos (left). Jessica and James on a trip to the Grand Canyon after they moved to Arizona to pursue her career as a range specialist (right). Photo: Jessica Orozco.

River in the southern Sierra Nevada, the eastern half of which is within the Tule River Indian Reservation. Under the guidance of RSABG's Dr. J. Travis Columbus, she worked with the people of the Tule River Indian Reservation to get permission to botanically survey the land and provide the tribe with the data she collected about the plants on the Tule River. In 2014, Jessica contacted renowned Navajo botanist Arnold Clifford in an attempt to reconnect with her Navajo roots. In June, she left with Arnold Clifford on a 12-week crash course in the Four Corners Region, studying plants, conducting botanical surveys, and going on a journey to learn about her Navajo culture (Fig. 3). This trip truly changed Jessica's life. Jessica excelled at bridging the gaps between indigenous knowledge of plants and their uses, and western approaches to botanical collection and plant identification, in order to learn from others, and then using that information to teach people about the plants around them with great enthusiasm and passion.

During her time at RSABG, she was a council member for the California Botanical Society. She organized the 2015 California Botanical Society Graduate Student Symposium and Annual Banquet at RSABG, a symposium that brings together students studying botany in western North America to present their research. During the symposium, she inspired the idea to start the Botany Ambassador Program, in which graduate students can participate in botanical outreach for K–12 youth a program which continues to grow and develop today.

It was also during her graduate study that, amidst great personal hardships, Jessica decided to become the legal guardian to her nephew James (Fig. 4). When the time came for James to need a parent, overnight Jessica became an amazing, committed single mom and had been his legal guardian since 2015. She referred to James as her "heart" and would often take him along on botanical trips. She would teach him about the plants and insects they would see, earning her the nickname "Aunty Bug".

Upon graduating, Jessica found her dream job as a Range Scientist with the Hualapai Nation Natural Resources Department in Peach Springs, Arizona. Jessica and James found their home within the Hualapai community, and Jessica was so excited to establish roots there and watch them grow. She worked with the 4H program as part of her job in the Natural Resources Department, and was able to share her knowledge of the plants and animals with the Hualapai youth a task she greatly enjoyed. She took her prior experiences learning desert ecology from Arnold Clifford in the Four Corners and doing surveys on the Colorado River to develop her knowledge and appreciation of southwestern desert flora. She had a continued interest from work in her graduate studies on the effect of ethnobotanical uses on the population genetics of chia (*Salvia columbariae* Benth.) along historical trade routes. At the time of her death, Jessica was still working on some of this work. From her amazing accomplishments over such a short career, there is no doubt she would have continued to make a huge impact on indigenous and botanical communities alike.

Jessica Orozco was a proud Native woman who was able to take all of the anguish and pain of the past, and transform it into a beautiful life, where she fought for the rights of the indigenous and refused to submit to the lasting effects of colonization. No matter how much time anyone spent with Jessica, she always left a positive impression. Her bright and bubbly nature could fill any room with laughter and smiles. She was a beacon of positive energy, and had been practicing Buddhism, where she was able to foster that incredible amount of energy and share it with others. Jessica was funny, unique, and sported a diverse collection of botanical tattoos including *Salvia columbariae, Hesperocallis undulata* A.Gray*, Limonium californicum* (Boiss.) A.Heller*, Lilium kellyanum* Lemmon (Fig. 5). Jessica had an unprecedented love and understanding of the Earth and all of its plants. As a botanist, she trudged through paths less

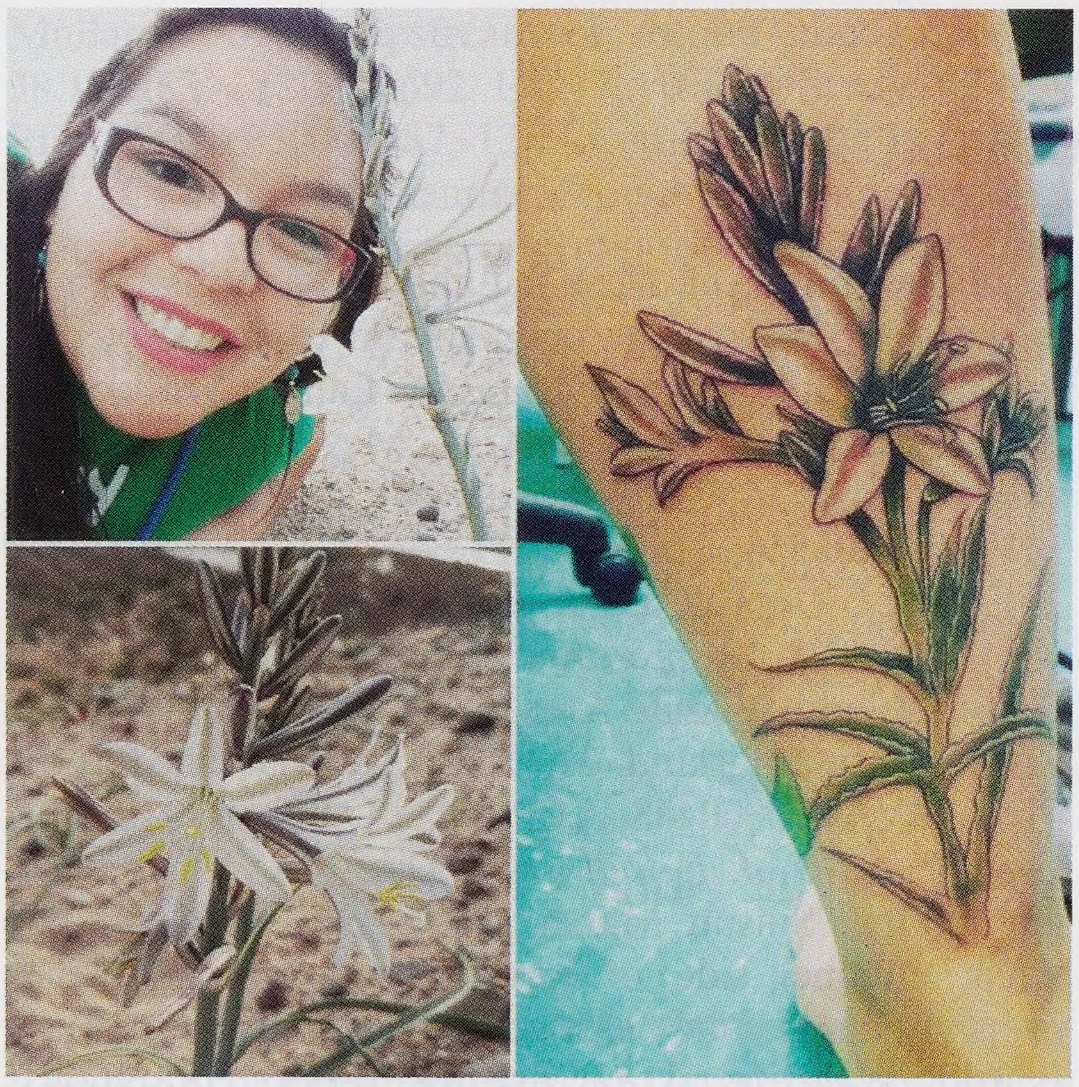

FIG. 5. Jessica Orozco had several botanical tattoos. She got this desert lily (*Hesperocallis undulata*) tattoo to commemorate her first year of living in Arizona, studying desert plants, and working with the Hualapai Nation Natural Resources Department. Photo: Jessica Orozco's Facebook Page.

traveled in order to shine light on plants that would have otherwise been overlooked. Her death is a truly a loss to the field of botany and anyone that had the privilege of knowing her. Through her studies, work, and adventures, Jessica encountered many people, and touched so many lives.

The authors thank Robert Freeman, Cassie Freeman, and Sandra Mardjonovic for sharing their thoughtful words in Jessica's obituary which was used in assembling this Dedication.

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NOTEWORTHY COLLECTIONS

CALIFORNIA

ALTERNANTHERA PHILOXEROIDES (Mart.) Griseb. (AMARANTHACEAE).—Contra Costa Co., Winter Island, 10S 600860N 4212403E (38.053758, –121.850386; utms converted with Yellowstone Research Coordination Network 2019), CDFA PDR MVAP50000489, SurveyID MAX1807310959, California Division of Boating and Waterways Management Site 133, 31 July 2018, *A. Ougzin and J. Mauldin s.n.* (CDA). Sacramento Co., Sacramento River, populations at pylons anchoring floating dock under Tower Bridge, 38.58014, –121.507721 (lat/long approximate from GoogleEarth Pro version 7.3.0.3830), CDFA PDR MVAP06805524, CalFlora ID po65735, California Division of Boating and Waterways Management Site 290, 22 September 2017, *G. Walden s.n.* (CDA); Sacramento River, floating dock under Tower Bridge, 38.579968, –121.507755 (lat/long approximate from GoogleEarth Pro version 7.3.0.3830), CDFA PDR MVAP50000219, California Division of Boating and Waterways Management Site 290, 19 July 2018, *G. Walden s.n.* (CDA); Sherman Island, alligatorweed with *Colocasia esculenta* (L.) Schott (Araceae), *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae), *Iris pseudacorus* L. (Iridaceae), *Ludwigia* sp. (Onagraceae), 10S 606711E 4210604N (38.036877, –121.783982), CDFA PDR MVAP50000499, SurveyID Alligator1808231, California Division of Boating and Waterways Management Site 122, 23 August 2018, *A. Ougzin and J. Mauldin s.n.* (CDA); Sacramento River, 10S 630796E 4256104N (38.443645, –121.501216), CDFA PDR MVAP50000484, California Division of Boating and Waterways Site 249, CDFA Noxious Weed permit number 3460 (form 66-026), 15 January 2019, *J. O'Brien, J. Martinez, and M. Kwong s.n.* (CDA). San Joaquin Co., southern Delta near the confluence of Salmon Slough and Old River, identified by D. Kratville from nutria camera trap, 37.80596, –121.40878, CDFA PDR MVAP50000482, 26 November 2018, *D. Kratville, S. Maring, and K. Norberg s.n.* (CDA). Solano Co., east bank Montezuma Slough, Montezuma Wetlands across from Grizzly Island, fringing emergent tidal wetland, floating mat and plants rooted in sediment, levee bank, 38.096641, –121.894088, CDFA PDR MVAP06805556, CalFlora ID po62366, California Division of Boating and Waterways Management Site 850, 25 August 2017, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); fringing emergent tidal wetland west bank of in-channel island, Montezuma Slough, Suisun Marsh at Grizzly Island Wildlife Area, 38.114364, –121.8913, CDFA PDR MVAP06805557, ALPH-1, CalFlora ID po62369, 12 September 2017, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); west side Montezuma Slough, Suisun Marsh immediately north of Grizzly Island Wildlife Area, southwest of Mein's Landing, floating mat in backwater area at edge of in-stream island, rooted in sediment, with *Azolla filiculoides* Lam. (Azollaceae), *Schoenoplectus californicus* (C.A. Mey.) Soják (Cyperaceae), 38.135535, –121.914477, CDFA PDR MVAP06805558, CalFlora ID po62373, 12 September 2017, *B. J. Grewell, C. J. Futrell, and J. Castillo s.n.* (CDA, DAV); Montezuma Slough, Suisun Marsh at Grizzly Island Wildlife Area, east side of small channel within in-stream island, 38.128201, –121.91626, CDFA PDR MVAP50000448, ALPH-4, 3 October 2018, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); Montezuma Slough, Suisun Marsh at Grizzly Island Wildlife Area, channel side of levee Montezuma Wetlands property immediately east across channel from Grizzly Island Wildlife Area fishing piers, 38.096641, –121.894088, CDFA PDR MVAP50000449, ALPH-1, 3 October 2018, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); Montezuma Slough, Suisun Marsh, west side of in-stream island at Grizzly Island Wildlife Area, south of ALPH-3, 38.127671, –121.916212, CDFA PDR MVAP50000450, ALPH-2, 3 October 2018, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); Montezuma Slough, Suisun Marsh, west side of in-stream island at Grizzly Island Wildlife Area, north of ALPH-2, 38.128027, –121.916337, CDFA PDR MVAP50000451, ALPH-3, 3 October 2018, *B. J. Grewell and C. J. Futrell s.n.* (CDA, DAV); Decker Island, intertidal area, in tules, not visible from water, in sand, 38.090850, –121.710820, California Department of Water Resources, CDFA PDR MVAP50000218, Division of Boating and Waterways Site 176, 11 July 2018, *J. Van Susteren JVS 18-54* (CDA); Montezuma Slough, Second Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000220, 10 July 2018, *T. O'Rear s.n.* (CDA); Montezuma Slough, Second Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000366, 16 August 2018, *T. O'Rear s.n.* (CDA); Cordelia Slough, just downstream of the railroad bridge, 38.152497, –122.088564, UC Davis Fish Study, CDFA PDR MVAP50000367, 16 August 2018, *T. O'Rear s.n.* (CDA); Montezuma Slough, Second Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000375, 11 September 2018, *T. O'Rear s.n.* (CDA); Cordelia Slough, just downstream of the railroad bridge, 38.152497, –122.088564, UC Davis Fish Study, CDFA PDR MVAP50000376, 13 September 2018, *T. O'Rear s.n.* (CDA); Montezuma Slough, Second Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000444, 11 October 2018, *T. O'Rear s.n.* (CDA); Montezuma Slough, Second

Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000487, 12 November 2018, *T. O'Rear s.n.* (CDA); Montezuma Slough, Second Mallard Slough, upstream of second major branch, 38.190283, –122.006692, UC Davis Fish Study, CDFA PDR MVAP50000488, 4 December 2018, *T. O'Rear s.n.* (CDA). Yolo Co., Sacramento River, in river on submerged pilings, east of Riverwalk Trail, just before (south) of Subtile Sculpture, 38.57657, –121.511472, CDFA PDR MVAP50000441, 20 October 2018, *G. Walden s.n.* (CDA); Sacramento River along banks, collected from 38.575783, –121.512295 to 38.574711, –121.513450, CDFA PDR MVAP50000483, 17 January 2019, *G. Walden s.n.* (CDA); Sacramento River under Mill Street Pier, 38.57317, –121.515169, CDFA PDR MVAP50000486, 27 February 2019, *G. Walden s.n.* (CDA).

Previous knowledge. Alternanthera philoxeroides (common name alligatorweed; basionym *Bucholzia philoxeroides* Mart., synonyms *Achyranthes philoxeroides* [Mart.] Standl., *Telanthera philoxeroides* [Mart.] Moq.) is native to South America, invasive, and a noxious weed worldwide (EPPO 2016; Bartlett 2018). In North America, *A. philoxeroides* occurs in México (Mora-Olivo and Sánchez-del Pino 2014) and the United States (Clemants 2004; USGS 2019). In the USA, *A. philoxeroides* has been reported from Alabama, Arkansas, California, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, and Virginia (Brown and Carter 1946; Coulson 1977; SEINet 2019; USDA, NRCS 2019; USGS 2019).

In California, *A. philoxeroides* was first documented in 1940 in Los Angeles Co. (CDA-0023860), determined as a noxious weed infestation requiring management in 1956 (CDA-0003253), and eventually found in waterways of Riverside (CDFA PDR 1036436, duplicates deposited at RSA, SD, UCR) and San Bernardino cos. (reports only, no supporting voucher specimen; Roberson 1996). *Alternanthera philoxeroides* was first documented in Tulare Co. in 1965 (CDFA 1965), spreading in Mill Creek to adjacent Kings Co. by 1969 (CDFA 1969). *Alternanthera philoxeroides* occurred in San Diego Co. in 1986 (CDFA PDR 478124, CDA-0003251) and was eradicated by 1994. The Los Angeles and Kings/Tulare county infestations are still extant and under management by County Agriculture Commissioners (CDFA 2019b). *Alternanthera philoxeroides* is an A-rated Noxious Weed [3 CCR § 4500] and Restricted Noxious Weed Seed [3 CCR § 3855] in California. The counties of Kings, Los Angeles, Riverside, and Tulare are alligatorweed eradication areas [3 CCR § 3960].

Alternanthera philoxeroides is adaptive, competitive, and plastic (Sosa et al. 2008). It is a perennial, stoloniferous, mat-forming macrophyte that roots at nodes; it reproduces vegetatively and can spread rapidly by hydrochorous dispersal of plant fragments (Keffer 1982; CDFA 2019a). Alligatorweed has diagnostic hollow stems in aquatic situations (from submerged or emerged conditions), and solid stems or solid nodes in terrestrial situations. Stems can be glabrous or with two lines of trichomes, and can have tufts of hair at the nodes. Leaves are opposite, sessile to slightly clasping, entire-margined, and can be variable in shape and size (Sosa et al. 2008). Inflorescences are axillary or terminal, peduncled, globose heads of densely clustered flowers. Mature fruits have not been reported in North America.

Alternanthera philoxeroides is a significant invasive species for California. It is highly competitive, displaces non-native and native wetland and riparian species, and causes severe impacts to infrastructure of waterways and irrigation systems (Bartlett 2018). Since management efforts for Los Angeles began in 1956, continued cooperative efforts, surveys, and funding have been required to control the more than 125 net acres (Hill and Donley 1973), and although still present in Los Angeles Co., the total area infested has been reduced to less than an acre (Kaplan 1994, Senzai 2006). Invasion and establishment of *Alternanthera philoxeroides* into new counties and water systems of California has long-term economic and environmental costs for management.

Significance. These are the first vouchers of *A. philoxeroides* from the Sacramento-San Joaquin Delta, Suisun Marsh, and its tributaries and the first collections in wildlands of Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties. A previous specimen from Danville, Contra Costa Co. is not considered a naturalized population, although information about this specimen is limited (hereafter Danville specimen, garden situation, CDA-0020558, 23 June 2005; CCH 2019; CDFA 2019b). Additional observations and reports have been made by members of the general public and by California State and Federal agencies as part of survey and management efforts; supporting voucher specimens are not currently known or available for all reported sites (CalFlora 2019; CDFA 2019a; CDFW 2019b; iNaturalist 2019).

Collections from 2017 by USDA-ARS in Montezuma Slough in Solano Co. were the first occurrences documented for Suisun Marsh, and outside of any previous known occurrences in California under management (i.e., Los Angeles Co. and area, and Kings/Tulare cos.). The 2017 collection by CDFA at Tower Bridge in Sacramento Co. was the first voucher within the legal boundary of the Sacramento-San Joaquin Delta. These vouchered finds led to inter-agency coordination to complete a risk assessment and determination as an invasive aquatic plant (Bartlett 2018) for management in California (O'Brien 2018; Sandoval 2019).

In total, these finds document a range expansion greater than predicted for California by Julien et al. (1995). The population at the Tower Bridge in

Sacramento Co. (at 38.58°N) represents the northernmost documented site for *A. philoxeroides* in California. This range expansion in California is similar to that documented for *A. philoxeroides* in China, where the species has spread to 36.7°N, five degrees latitude beyond the predicted northern limit (Julien et al. 1995; Liu et al. 2012; Liu et al. 2019). For North America, the northernmost occurrence is in Maryland at 38.98°N [16 September 2014, *J. D. Hall JH2014.09.16-07 with N. G. Anderson* MARY1000869; available via SEINet (2019)].

Limits for *A. philoxeroides* in the Sacramento, American, and San Joaquin rivers of California are not yet known. Heightened awareness is needed for early detection in the Sacramento-San Joaquin Delta, Suisun Marsh, and its tributaries, and in irrigated and flood crops of the Great Central Valley. The Suisun Bay drainage was included in climate matching analyses due to the Danville specimen for California (see Figs. 5–7 in USFWS 2018); those analyses indicate additional available climate matches outside of vouchered and reported sites for *A. philoxeroides* invasions. Re-evaluation of datasets and models for predicting invasion distributions are needed for this taxon, especially for pest risk assessments and introductions of biocontrol organisms into California.

If plants suspected to be *Alternanthera philoxeroides* are observed, please notify your nearest California Agricultural Commissioner office immediately [https://www.cdfa.ca.gov/exec/county/countymap/]. Submit plant samples to the Agricultural Commissioner office for official determination and voucher at the CDFA Plant Pest Diagnostic Center, and to coordinate interagency management response.

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ACKNOWLEDGMENTS

We thank the following people and agencies for their help: Cynthia Powell (CalFlora); Debbie McGinnis (Center for Watershed Sciences, UC Davis); Caryn Joy Futrell, Morgane Gillard, Christy Morgan, and Paul Pratt (USDA-ARS Invasive Species and Pollinator Health Research Unit); Eddie Hard (California Natural Resources Agency, California Department of Parks and Recreation, Division of Boating and Waterways); Lesley Hamamoto (California Natural Resources Agency, California Department of Water Resources, Division of Environmental Services); Michelle Dennis, Kenneth Norberg, and Michael Pitcairn (California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Integrated Pest Control Branch); Cheryl Blomquist, Steve Gaimari, Adam Holmes, Umesh Kodira, Debbie Meyer, and everyone at the Plant Pest Diagnostic Center (California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Plant Pest Diagnostic Center); and members of the Alligatorweed Working Group.

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MADROÑO, Vol. 66, No. 1, pp. 8–9, 2019

NOTEWORTHY COLLECTION

CALIFORNIA

MALOSMA LAURINA (Nutt.) Nutt. ex Abrams (ANACARDIACEAE).—San Bernardino Co., SW foothills of San Bernardino Mts., Rancho Muscupiabe at Badger Hill Preserve CSU San Bernardino, 0.1 km SE of benchmark "Badger 1854" on steep hillside, solitary shrub in coastal sage scrub, San Bernardino North USGS 7.5 minute topographic quadrangle, 34° 11′ 8.39″ N [34.185664°], 117° 18′ 51.45″ W [–117.314292°], ca. 518 m, 27 Apr 2018, *Brett R. Goforth s.n.* (RSA 868368); Riverside Co., SE foothills of San Bernardino Mts., Whitewater Canyon Preserve, E of "Trout Pond" at base of canyon wall drainage, 0.6 km NW of BM 2114, 47 shrubs in desert scrub, NE ¼ sec. 22, T2S, R3E, S.B.B.M, White Water 7.5 min quad., 33° 59′ 19.25″ N [33.988681°], 116° 39′ 17.60″ W [-116.654889°], ca. 680 m, 3 May 2018, *Brett R. Goforth s.n.* (RSA 868367).

Previous knowledge. *Malosma laurina* has a disjunct distribution range in SW North America along the Pacific Coast and inland to the Sonoran Desert edge, collected from the Sierra de la Laguna at Lat. 23° 30′ N in the Cape region of the Baja California Peninsula (SD 49030), poleward to Lat. 35° N in San Luis Obispo Co., CA (UC 1130505, OBI 48379), including the islands of Cedros, Guadalupe, Todos Santos, San Clemente, and Catalina (Wiggins 1980; Wallace 1985; Keil 1990; Lenz 1992; Junak and Philbrick 1994; Turner et al. 1995). The broad-leaves and stems of this evergreen woody shrub are intolerant of freezing temperatures, which cause freeze-thaw embolism injury and death of shoots sprouted from a root crown (Pratt et al. 2005). In southern California, *M. laurina* is common on dry slopes and canyons in shrublands below ca. 1000 m near the coast, though scarce at interior range limits because of susceptibility to frost (Munz 1974; Smith 1976; Beauchamp 1986; Raven et al. 1986; Roberts et al. 2004; Clarke et al. 2007; Roberts 2008). There are apparently no previous collections from the San Bernardino Mts. based on a search of the Consortium of California Herbaria database (CCH 2018). An unvouchered report of *M. laurina* at Whitewater Canyon was previously noted (Krantz 1994), but this species is not included in the checklist of 524 vascular plant taxa collected from the locality (Chester 2010).

Significance. These are the first collections of *M. laurina* to be reported from the San Bernardino Mts. The two collection localities are 65 km apart, resulting in range extensions of 18 km NE in San Bernardino Co., and 58 km E in Riverside Co. The nearest collections recorded by CCH are located at Fontana (SD 146056, UCR 113238; 18 km SW from Badger Hill, 73 km W from Whitewater Canyon), the Jurupa Hills (UCR 103864, RSA 604049, RSA 543128; 20–22 km SW from Badger Hill, 72–73 km W from Whitewater Canyon), Etiwanda Wash south of the San Gabriel Mts. (UCR 97387; 21 km W from Badger Hill, 83 km NW from Whitewater Canyon), and Pigeon Pass in the Box Springs Mts. (CLARK-A1528-5483, UC 1042990; 21 km S from Badger Hill, 58 km W from Whitewater Canyon). An anomalous occurrence mapped by CCH at ca. 1480 m elevation near Keen Camp Summit in the San Jacinto Mts. (IRVC79; 79 km SE from Badger Hill, 34 km SW from Whitewater Canyon) could not be confirmed by field survey on 29 June 2018; the specimen is from a high school student collection lacking calendar date and field notes.

At Badger Hill Preserve, the single individual of *M. laurina* is an arborescent shrub growing on a SE aspect backslope of 40° angle. The canopy was measured at 4 m height and 6 m diameter, with the largest stem 7 cm DBH. Flowers collected on 11 July 2018 were pistillate with vestigial stamens (Miller and Wilken 2012). A sample of 35 inflorescences collected on 12 Sept 2018 contained no fruit. Soils are shallow with a gravelly loam texture derived from weathered schist, and classify as loamy, mixed, superactive, thermic Lithic Haploxerolls mapped in the Friant Series (Woodruff 1980). A mean annual precipitation of ca. 40 cm is registered by a rain gauge located 1.2 km W at 470 m elevation (San Bernardino County 2018). Frost occurrence is likely inhibited by equator-facing aspect and cold-air drainage off the hillside. Associated species include *Adenostoma fasciculatum* Hook. & Arn., *Bromus diandrus* Roth, *B. madritensis* L. subsp. *rubens* (L.) Husn., *Centaurea melitensis* L., *Cryptantha clevelandii* Greene, *Dichelostemma capitatum* (Benth.) Alph. Wood, *Eriogonum fasciculatum* Benth., *Hirschfeldia incana* (L.) Lagr.-Fossat, *Salvia apiana* Jeps., and *S. columbariae* Benth.

At Whitewater Preserve, a small population of shrubs was clustered at the base of an east canyon wall drainage, on a W aspect footslope of 15°, uphill from "Trout Pond" where groundwater seepage occurs along a fault line mapped in the San Andreas-Banning zone (Yule and Sieh 2003). Shrub canopies had up to 3 m height, sprouted from separate root crowns. A census of the population on 31 Aug 2018, counted 47 individuals, of which 42 had bisexual flowers with 25 in fruit, and 2 were staminate (Miller and Wilken 2012). Three could not be examined because of inaccessible location. Charred dead branches were found at the root crowns of 5 individuals, indicating their canopies were sprouted after the site had burned. This site is located inside the mapped perimeters of wildfires that

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Congratulations to the following winners of the 27th Graduate Student Symposium

April 2019 Cal Poly, San Luis Obispo

Natalie Love, University of California, Santa Barbara: A new quantitative phenological metric for use in pheno-climatic models: a case study using herbarium specimens of *Streptanthus tortuous* (Best Overall Presentation)

San Luis Obispo Serpentine field trip with Nishi Rajakaruna (5 April 2019)
Photo Credit: Lacey Benson

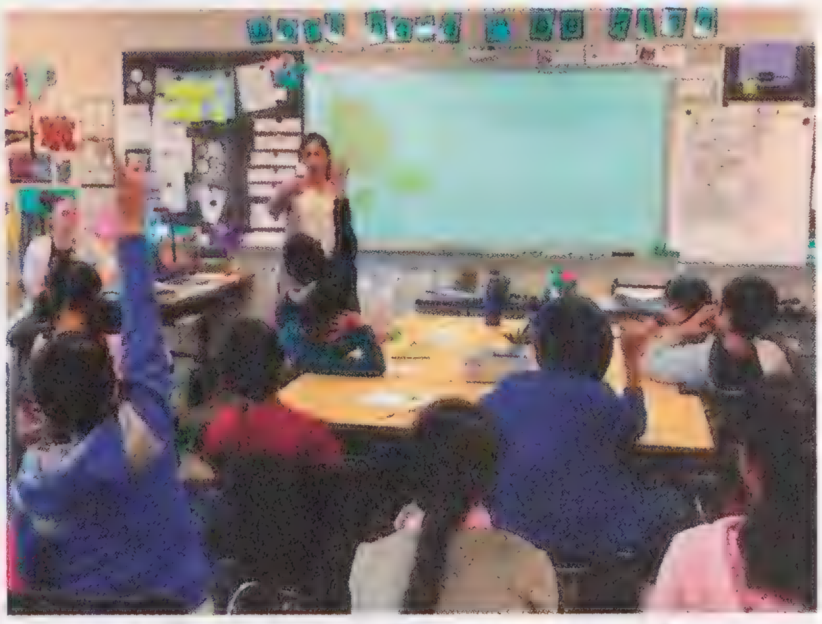
Emily Cox, University of California, Berkeley: *Lasthenia gracilis* and water stress: A glimpse into the future of California grasslands (Best Talk)

Erin Coltharp & Chloe Knowd, California Polytechnic State University, San Luis Obispo: Oak (*Quercus agrifolia*) leaf domatia-mite mutualism (Joint Winner Best Poster)

Nancy Conejo, San Francisco State University: Biogeography of the whorled wattles (*Acacia* section *Lycopodiifoliae*) in the Australian Monsoon Tropics (Joint Winner Best Poster)

Botany Ambassador in the Classroom

For the second year in a row, Sraavya Sambara, a high school student and member of the Rothfels lab at UC Berkeley, has been teaching special botany classes to 4th and 5th graders at Bella Vista Elementary School in San Ramon, CA.



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Congratulations to the following winners of the 2019 CalBotSoc Student Science Fair Prizes

2019 Synopsys Championship (Santa Clara County, California)

Justen Whittall, *Madroño* Editor (center)

Royal Huey III: Effects of simulated microgravity through perpetual falling on *Raphanus raphanistrum* root network development (1st place High School division)

Charlotte Lara: Allelopathic effects of California native trees on a California native grass, *Fistula californica* (2nd place High School division)

Brian Chen: Validating novel algorithm generated crop rotations (1st place Middle School division)

Vishnavi Katta, Ruhi Batchu (not pictured): Watering efficiently (2nd place Middle School division)

2019 Santa Cruz County Science & Engineering Fair

Katherine McCormick, Helen Leslie Schafer-Dews, San Lorenzo Valley High School, Felton, CA, Ruby Howard, Coast Redwood High School, Felton, CA: Water Percolation in Relation to the Quantity of French Broom in the San Lorenzo Valley Watershed (1st place High School division)

Trevor Cambron, Natalie Owens, San Lorenzo Valley High School, Felton, CA: Trails, Soil, and SOD (2nd place High School division)

Ruby Evans, San Lorenzo Valley Middle School, Felton, CA: Do Plants Absorb Microplastics (1st place Middle School division)

Eva Ramirez-Truse, Santa Cruz Children's School, Santa Cruz, CA: Which Trees Take the Longest to Burn (2nd place Middle School division)

Jonica Wilson, Pacific Elementary School, Davenport, CA: The Effects of Wildfire on Seed Germination of Native and Invasive Plants of California's Monterey Pine Forests (1st place Elementary School division) occurred in 1995 and 1980 (Cal Fire 2018). Soils are shallow with gravelly sand texture derived from conglomerate, and classify as Lithic Torripsamments (Knecht 1980). Associated species include *Artemisia californica* Less., *Avena barbata* Pott ex Link, *Bahiopsis parishii* (Greene) E.E.Schill. & Panero, *Bebbia juncea* (Benth.) Greene var. *aspera* Greene, *B. diandrus*, *B. madritensis* subsp. *rubens, Cryptantha barbigera* (A.Gray) Greene, *Datura wrightii* Regel, *Dudleya lanceolata* (Nutt.) Britton & Rose, *Encelia actoni* Elmer, *E. farinosa* A.Gray ex Torr., *Ericameria paniculata* (A.Gray) Rydb., *Eriodictyon trichocalyx* A.Heller, *Eriogonum fasciculatum* var. *polifolium* (Benth.) Torr. & A.Gray, *Marah macrocarpa* (Greene) Greene, *Mirabilis laevis* (Benth.) Curran var. *villosa* (Kellogg) Spellenb., *Pluchea sericea* (Nutt.) Coville, *Prosopis glandulosa* Torr. var. *torreyana* (L.D.Benson) M.C.Johnst., *Rhus ovata* S.Watson, *Salvia apiana,* and *Schismus barbatus* (L.) Thell. It is possible that *M. laurina* was introduced at this locality because non-native *Robinia pseudoacacia* L. is naturalized at the historical site of a fish hatchery nearby in the Preserve. However, the population of *M. laurina* is well established and occurs sympatric with multiple species of coastal sage scrub that have interior range limits at low elevation habitats on the edge of the Sonoran Desert where frost is rare.

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MADROÑO, Vol. 66, No. 1, p. 10, 2019

NOTEWORTHY COLLECTION

CALIFORNIA

STREPTANTHUS CORDATUS Nutt. VAR. CORDATUS (BRASSICACEAE). — Siskiyou Co., County Road 17 (FR 42N17) to Mt Eddy, 41° 14′ 37.896″, -122° 07′ 06.24″, road cut, June 15, 2018 (JEPS105539). Small groups and individuals of *S. cordatus* var. *cordatus* (hereafter referred to as *S. cordatus*) grow on the road cut for 1-2 km . Hundreds of plants are present from late May through June only a few meters from the road.

Previous knowledge. Prior to this discovery, the western-most location for *S. cordatus* var. *cordatus* was Magalia, Butte Co., CA (CAS-BOT-BC1285 J.T. Howell). Although this occurrence of *S. cordatus* is on serpentinite-derived soil and in the partial shade of an open pine forest, *S. cordatus* thrives in many different habitats and substrates (O'Donnell, personal observation). According to the Flora of North America (Al-Shehbaz 2010), *S. cordatus* is widespread and abundant in the juniper-piñon woodlands, sagebrush and open pine forests, from Colorado, Wyoming, Utah, Idaho, Nevada, Arizona and New Mexico, west to California and north to eastern Oregon. I have seen it as far north as Canyon Mountain in northeastern Oregon growing in serpentinite-derived soil, and several places nearby. In the northern Warner Mountains, just south of the Oregon border, *S. cordatus* grows along the road to Lily Lake in volcanic talus. In southeastern Oregon, it grows in volcanic soil on Steens Mountain. Although I collected no voucher specimens at these sites, others have (on the road to Lily Lake: L.S. Smith, 1918, JEPS27101; at the crest of Fandango Pass: Alice Eastwood and J.T. Howell, 1940, POM260726; in the hills above Cedar Pass: Owenby and Meyer, 1940, VC705857; Steens Mt., Arthur Cronquist 8593; Steens Mt., June 30, 1959; WTU 207602).

Significance. The new Mt. Eddy location is the westernmost observation of this species. Even more importantly, it has not been reported previously from Mt. Eddy or the Klamath Mountains (Smith 2010; Smith and Sawyer 2010). Mt. Eddy is a botanical hotspot in northern California and has been a destination for hikers, campers, and naturalists for many decades. FR 42N17 is the main route to the heavily used trailhead to Mt. Eddy's summit. With such heavy traffic for so many years, it is puzzling that *S. cordatus* has not previously been reported at this site.

There are two plausible reasons why *S. cordatus* on FR 42N17 to Mt. Eddy has been unreported until now. First, it may have been overlooked since dangerous road conditions make stopping at this spot challenging. Second, the species might have been observed at this site, but it was neither collected, nor reported. The simplest explanation is that few people stop along this dangerous stretch of road near the population of *S. cordatus*. The inaccessibility is compounded by the presence of a morphologically similar congener, further reducing the chances of detecting this species. Yet, at least two other botanists (Nick Jensen [Rancho Santa Ana Botanic Garden] and Ryan O'Dell [Bureau of Land Management], personal communications) have noted *S. cordatus* from this site, but this is the first reported collection of this species from this location.

Detecting *S. cordatus* along FR 42N17 is difficult for two reasons: First, access to the site requires a level of risk that most drivers would probably find unacceptable. The road is narrow with a steep drop-off, making it appear to be unsafe to park. Second, the gross morphological similarity of *S. cordatus* to *S. barbatus* S.Watson, a co-occurring congener and resident endemic crucifer, might conceal its presence. Easily distinguished from one another at close range, *S. cordatus* and *S. barbatus* have a similar habit and can be mistaken from a distance. Both species are of similar height and have leathery to succulent stems and leaves. The cauline leaves are reduced upward and do not reach the inflorescence. The flowers are initially confined to the top of the stem, deploying along its upper reaches with maturity. The two species are so similar in habit that I failed to detect the presence of *S. cordatus* even after some hours photographing *S. barbatus* along the roadcut in 2003. When reviewing the photos later, I saw in the background a blurred image that reminded me of *S. cordatus*. I returned to the site the next day to confirm that the image was of *S. cordatus* and saw that there were quite a few *S. cordatus* plants scattered among the *S. barbatus,* none of which I had noticed the day before.

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MADROÑO, Vol. 66, No. 1, p. 11–12, 2019

NOTEWORTHY COLLECTION

OREGON

PETROSELINUM SEGETUM (L.) Koch. (APIACEAE) .—Douglas Co., along State Hwy 42 ca. 2.2 miles northeast of Camas Valley; flowers lavender, plants faintly aromatic; gravel road shoulder with *Aira, Lotus, Conyza, Daucus, Hypochaeris, Epilobium;* 43.06534°, –123.64991°, 423 m, 29 September 2006, *Richard R. Halse 7071* (OSC), determined by C. Danderson and S. Downie; East entrance to North Bank Habitat Management Area, BLM, 9.9 air miles northwest of downtown Roseburg; gravelly road shoulder and adjacent dry meadow with *Hypochaeris, Bromus, Schedonorus, Dipsacus;* 43.3168°, –123.2002°, 198 m, 20 July 2007, *R. E. Brainerd 916* (OSC); Roseburg; petals white at maturity, anthers purple-tinged; growing at edge of lawn and becoming weedy throughout town; 43.2181°, –123.3392°, 155 m, 29 August 2012, *Richard Helliwell 3987* (OSC); Benton Co., Northwest Corvallis, Walnut Boulevard just south of entrance to Martin Luther King Park parking area; flowers white to light pink, abundant, thousands of plants; mowed lawn of parking strip with *Lolium, Agrostis, Hypochaeris, Schedonorus, Daucus, Trifolium;* 44.5905°, –123.3076°, 121 m, 26 July 2012, *R. E. Brainerd 2051* (OSC); Northwest Corvallis, Crescent Valley High School at west end of parking lot near the softball diamond; flowers pinkish when young, turning white, plants to 50 cm tall, aromatic, thousands of plants present; lawns and pavement cracks with *Schedonorus, Bromus, Trifolium, Hypochaeris;* 44.6152°, –123.2663°, 91 m, 3 July 2013, *R. E. Brainerd 2173* (OSC); Corvallis, Crescent Valley High School off of Northwest Highland Drive; flowers lavender, plants faintly aromatic; common weed in lawn with *Taraxacum, Daucus, Hypochaeris;* 44.615079°, –123.266351°, 87 m, 25 August 2018, *Richard R. Halse 10449* (OSC).

Previous knowledge. A native of Europe, corn parsley is found from the Netherlands and United Kingdom to Portugal and Italy (Tutin et al. 1968).

Significance. First report for Oregon and the United States. Reports of *Pimpinella saxifraga* L. from Benton and Douglas cos., Oregon in the second edition of the *Flora of the Pacific Northwest* (Giblin et al. 2018) are based upon misidentifications of *Petroselinum segetum*.

TROPAEOLUM MAJUS L. (TROPAEOLACEAE).—Lincoln Co., east side of Highway 101 at its intersection with the road to Cape Foulweather; flowers yellow, sprawling on roadside at edge of conifer forest with *Stellaria media* (L.) Vill.; 44.76054°, –124.06227°, [175 m]; 5 December 2007, *Barbara Wilson 14518* (OSC); Curry Co., Harbour, near 15504 Lilyfield Lane; plants more or less succulent, clambering through and on adjacent vegetation, flowers orange; coastal bluff with *Athyrium, Salix, Rubus, Equisetum, Vicia, Scophularia, Zantedeschia;* 42.028681°, –124.251778°, 6 m, 14 September 2018, *Richard R. Halse 10458* (OSC).

Previous knowledge. Garden nasturtium, a native of South America, is commonly cultivated; in California it is found naturalized from the North Coast to the South Coast ecoregions (Preston and McClintock 2012).

Significance. First reports for Oregon.

VALERIANELLA DENTATA (L.) Pollich. (VALERIANACEAE).—Benton Co., northwest Corvallis, Timberhill area just east of trail to Chip Ross Park, 84 m northeast of Huckleberry Drive; annual to ca. 40 cm tall, corolla light pink to white, many plants forming large dense patches; seasonally moist meadow on gentle south aspect with *Schedonorus, Camassia, Dichelostemma, Plantago, Sherardia, Daucus, Leucanthemum;* 44.6027°, –123.28422°, 67 m, 22 May 2014, *R. E. Brainerd 2295* (OSC, WILLI); Corvallis, at the end of N.W. Huckleberry Drive, ca. 45 m east of where the street dead ends; flowers pale blue; open sunny meadow with *Camassia, Danthonia, Rubus, Festuca, Cynosurus, Leucanthemum;* 44.600169°, –123.28441°, 99 m, 22 May 2018, *Richard R. Halse 10279* (OSC, WILLI); Wren, at Fenders Blue butterfly site, dry grassland, abundant in Wren area; 44.5912°, –123.4106°, 126 m, 2 June 2016, *Duncan Thomas 13300* (OSC); Bald Hill Natural Area, west Corvallis, 1.1 km west of the Benton County Fairgrounds, 220 m NNW of the Reservoir Road parking area, along trail to summit, west of paved bicycle path; flowers light pink to white, several hundred plants observed; disturbed, seasonally moist grassland with *Festuca, Cynosurus, Bromus, Taeniatherum, Daucus;* 44.56292°, –123.33007°, 110 m, 27 May 2018, *R. E. Brainerd 2758* (OSC, WILLI).

Previous knowledge. Toothed or narrow-fruited corn salad, a native of Europe, Central Asia, and North Africa (Coode and Matthews 1972) is known in North America from Alabama, Georgia, and Tennessee (Natural Resources Conservation Service 2019) and Arkansas (Ware, unpublished data).

Significance. First reports from Oregon.

VALERIANELLA ERIOCARPA Desv. (VALERIANACEAE).—Douglas Co., Roseburg, Highway 42/99 between Interstate Highway 5 and the Shady Oaks

Motel, south of the road where there is an extra paved lane; disturbed, very weedy area; 43.17439°, –123.36181°, elev. 152 m, 29 June 2011, *Barbara L. Wilson 16664* (OSC, WILLI); Benton Co., Northwest Corvallis, Timberhill area just east of trail to Chip Ross Park, ca. 400 m east of the end of 29th Street; annual, 3–4 cm tall, flowers light pink, calyx tooth one; weedy upland meadow with *Danthonia, Plantago, Schedonorus, Daucus, Sanicula, Lathyrus;* 44.60326°, –123.28427°, 152 m, 12 May 2014, *R. E. Brainerd 2292* (OSC, WILLI); Northwest Corvallis in vacant area south of Ponderosa Avenue and northwest of Martin Luther King Park, 300 m northwest of the MLK Park Barn; flowers light pink, several patches totaling thousands of plants; moist weedy meadow at toe of south-facing slope with *Brachypodium, Daucus, Schedonorus, Valerianella locusta;* 44.59434°, –123.31218°, 138 m, 15 May 2017, *R. E. Brainerd 2555* (OSC, WILLI).

Previous knowledge. Italian or hairy-fruited corn salad is known from Turkey, Europe and North Africa (Coode and Matthews 1972) where it is native. It has been introduced into South Africa, Chile and Australia (Discover Life 2019).

Significance. First reports from Oregon and the United States. *Valerianella eriocarpa* as used here includes *V. muricata* (Stev.) Baxt. The two taxa differ only in their fruits (Coode and Matthews 1972), and the Oregon material is the *V. muricata* morphology. Whether this fruit variation represents genetic fruit polymorphism as found in some species of North American *Valerianella* (Eggers Ware 1983) is currently under study (Z. Kaplan, Czech Academy of Sciences, personal communication).

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MADROÑO, Vol. 66, No. 1, p. 13, 2019

NOTEWORTHY COLLECTION

WASHINGTON

CALOCHORTUS NITIDUS Douglas (LILIACEAE). — Whitman County, Steptoe Butte, remnant native Palouse prairie grassland on north-facing slope, vicinity of 47.033469°, –117.306148°, 860–880 m, *Riser 392* and *Riser 393*, 19 July 2016 (WS). Over 100 individual plants found in small rills and gullies at base of north-facing slope. Associated species include: *Achillea millefolium* L., *Berberis repens* Lindl., *Festuca idahoensis* Elmer, *Gaillardia aristata* Pursh, *Geranium viscosissimum* Fisch. & C.A.Mey. ex C.A.Mey., *Geum triflorum* Pursh, *Hieracium scouleri* Hook. var. *albertinum* (Farr) G.W.Douglas & G.A.Allen, *Iris missouriensis* Nutt.,, *Pseudoroegneria spicata* (Pursh) Á.Löve, and *Symphoricarpos albus* (L.) S.F.Blake.

Previous knowledge. *Calochortus nitidus* is known in Washington from a small number of early collections from eastern Whitman County. The last unequivocal documented collection of *C. nitidus* from Washington is the *Park s.n.* collection in 1923. A 1938 collection by Marion Ownbey (*Ownbey 1855*) has conflicting locality information: "4 miles east of Tekoa", which places it across the state line in Idaho. It was likely collected in Idaho and mislabeled as being from Washington. Outside Washington, *C. nitidus* is found at numerous sites in Idaho, occurring in various grassland vegetation associations in Benewah, Clearwater, Idaho, Latah, Lewis, and Nez Perce Counties.

Significance. The last sighting of this species in Washington was during a 1995 vegetation survey in nearby Asotin County on the Umatilla National Forest in the Lick Creek drainage (T9N, R43E, Sec 15). At this time, a specimen was collected by Karl Urban and sent to Douglass Henderson at the University of Idaho Stillinger Herbarium (ID) for identification. Efforts to find this specimen and any associated correspondence have been unsuccessful, and it appears to have never been incorporated into the herbarium collections and is likely lost. However, a color photograph taken by Karl Urban at that time shows that this is clearly *C. nitidus*. Subsequent surveys have failed to relocate plants at this occurrence (M. Darrach, University of Washington Herbarium, personal communication). This new 2016 population represents the first documented occurrence of *C. nitidus* in Washington since 1995 and the first occurrence in Whitman County since 1923.

Most of the early Whitman County records lack detailed locality information or habitat descriptions. However, when these data are present they indicate an affinity for lower-lying areas: "Bottom land." (*Hunter s.n.*, 1899), "Dry field." (*Park s.n.*, 1923), "Border of wet meadow." (*Suksdorf s.n.*, 1916), "In flats." (*Pickett 553*, 1916), "In low ground." (*Piper s.n.*, 1894), "Dried swales." (*Henderson 2484*, 1892), "In low bottoms." (*Lake 618*, 1892). *Calochortus nitidus* was likely never particularly common in Washington and was presumed extirpated from the state when these areas were extensively converted to agriculture in the early 20th century. In fact, Ownbey (1969) stated "...*C. nitidus* grows in potential farm land. As a consequence, it has become one of the rarest of our species of *Calochortus*. In the last 25 years, perhaps half of its known populations – none very large – have been destroyed." As far as can be determined from available specimen label data, no *C. nitidus* occurrences from Washington are known from upland habitats. However, in Idaho *C. nitidus* is more commonly found growing in upland grassland habitats (e.g., the populations south of Grangeville occurring on the ridges above the Salmon River). In Latah County (Idaho), near the Washington-Idaho state line, *C. nitidus* was historically recorded from both low-lying ["Low meadow" (*Ownbey 1854*, 1938), "Lowlands in fescue-wheatgrass prairie" (*Daubenmire 38264*, 1938)] as well as upland habitats, such as the slopes of Tomar Butte (e.g., *Baker 14418*, *14480*, *14484*, all 1956). It was likely extirpated from these low-lying sites when they were converted to cropland and is now infrequently found in upland native Palouse prairie grassland remnants that were too rocky for agriculture and thus preserved.

During the course of additional survey work, a second Washington population of *C. nitidus* was subsequently found on 28 July 2016 by J. Riser on private land northeast of Oaksdale; however, detailed locality information is being withheld to protect the landowner's privacy. It is likely there are additional populations in Whitman County, but the lack of access to private lands will continue to hinder survey efforts.

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ACKNOWLEDGMENTS

Kent and Elain Bassett and Joan and Ray Folwell deserve special thanks for their dedication to preserving native Palouse prairie grasslands and for permission to collect on their Steptoe Butte property. The Marion Ownbey Herbarium (WS) at Washington State University facilitated specimen loans.

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Madroño, Vol. 66, No. 1, pp. 14–23, 2019

OLD-GROWTH CHARACTERISTICS ON A COAST REDWOOD (*SEQUOIA SEMPERVIRENS* (D. DON) ENDL.) PYGMY FOREST ECOTONE

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Abstract

Old-growth *Sequoia sempervirens* (D. Don) Endl. (Cupressaceae) forests are commonly assumed to be populated by massive trees, but those growing on nutrient poor soils can be stunted and display unusual growth-forms. We characterized soils, stand structure, growth form, and crown complexity using a combination of random and targeted stratified sampling across an old-growth redwood/pygmy forest ecotone. ANOVA indicated significant variation in stand structure metrics and soil characteristics [pH, cation exchange capacity (CEC), and nutrient availability] among strata, with tree height, basal area, and the relative dominance of redwood-associated species declining under the influence of pygmy forest soils; while shrub cover and the dominance of pygmy associated species increased. Pearson's coefficients indicated positive correlations between tree height and diameter with CEC, P, K, Ca, and Na. Stepwise linear regression suggested that P, K, and CEC were the strongest predictors of tree height and diameter. Growth form and crown structure of *S. sempervirens* also varied considerably across the ecotone, with stunted multi-stemmed individuals and clusters of small diameter trees observed where pygmy soil conditions were most extreme, and larger, but still stunted ancient redwoods with complex crown structures, resident epiphytes, and large fire hollows, existing on the edge of the pygmy forest. The ancient redwoods sampled within the old-growth/pygmy ecotone were remarkably small in stature, yet contained many of the same structural characteristics associated with the largest and oldest *S. sempervirens*.

Key Words: Cation exchange capacity, crown structure, epiphyte, phosphorus, podsols, potassium.

The coast redwood forest of northern California is dominated by *Sequoia sempervirens* (D. Don) Endl. (Cupressaceae), a species that can live for more than 2500 years, and grows to heights exceeding 100 meters on productive soils (Sillett and Van Pelt 2000b). The term "old-growth" is traditionally defined by an absence of substantial logging history (Peterken 1996; Frelich and Reich 2003), but certain characteristics have become associated with these relatively undisturbed stands. First, certain structural characteristics, including fire hollows, complex crown structures, and epiphytic communities, are generally limited to ancient trees (Helms 2004; Spies and Duncan 2009). These features are important ecologically, as they reflect a life history punctuated by stochastic disturbance, and provide habitat for a variety of wildlife species (Sillett and Van Pelt 2000a, Spickler et al. 2006; Sillett and Van Pelt 2007). Second, large tree size and low stand density have also been commonly associated with old-growth, but this pattern may be due more to site productivity than to management history (Gerhart 2006). While large trees are often found on productive sites, old-growth stands that persist on marginal sites can exhibit relatively high stand densities and relatively small tree sizes (Berrill et al. 2017). And while trees on marginal sites tend to be small in stature, the level of stress and disturbance that they experience may allow them to develop structural complexity comparable to trees on productive sites (Wardle 1993).

Crown Complexity in Old-Growth Forests

The development of complex structural features in the forest canopy appears to be a function of age and disturbance history, rather than tree size (Wardle 1993; Ishii et al. 2004). Young *S. sempervirens* trees exhibit strong apical dominance with an orthotropic and monopodial main trunk, characterized by straight vertical growth and branching originating from a single axis (Harris and Harris 2001; Sillett and Van Pelt 2007). Apical dominance declines with age, and with the help of stochastic events such as wind, lightning, and mechanical damage, crown structure is reshaped. Codominant trunks are common in older specimens of *S. sempervirens*, and in some cases can result in reiterated trees high in the canopy (Sillett and Van Pelt 2000a; Shigo 2008). Large lateral branches are also formed, which provide habitat features in the form of deep crotches and platforms, and vegetative sprouting from the tree bole allows for the creation of epicormic branches and root growth into arboreal soils. As a result, the canopies of *S. sempervirens* are more complex than any other coniferous species (Sillett and Van Pelt 2000b).

The ecological value of this complexity is measured in the diversity of species that it supports. Epiphytic plants inhabit arboreal soils created from leaf litter, redwood bark, and dead roots, on lateral structures high in the tree's crown, and commonly include species such as *Vaccinium ovatum* Pursh (huckleberry) and *Polypodium scouleri* Hook. and Grev. (leather fern) (Sawyer et al. 2000). These epiphytic communities, in turn, provide habitat for wildlife species such as *Aneides vagrans* (Wake & Jackman 1998) (wandering salamander), a species that spends in entire life cycle in the forest canopy (Zielinski and Gellman 1999; Enloe et al. 2006; Spickler et al. 2006; Sillett and Van Pelt 2007). Mossy lateral branches provide nesting habitat for endangered avian species including *Brachyramphus marmoratus* (Gmelin and JF 1789) (marbled murrelet) and *Strix occidentalis caurina* (Merriam 1898) (northern spotted owl) (LaHaye and Gutiérrez 1999; Sillett and Van Pelt 2000a; Baker et al. 2006). Large persistent fire caves, both at the base of trees, and in the canopy, provide habitat for *Sitta pygmaea* Vigors 1839 (pygmy nuthatches), *Tyto alba* (Scopoli 1769) (barn owls), nesting *Tachycineta thalassina* (Swainson 1827) (violet-green swallows), in addition to a variety of species of spiders and bats (Zielinski and Gellman 1999; Willet 2001). The result is a complex community that is dependent on features that develop on ancient trees (Nadkarni 1994). In total, old-growth redwood forests provide habitat for 42 vertebrate species listed by state and federal agencies as endangered, threatened, or a species of special concern; and four invertebrate species listed as endangered or threatened (Cooperrider et al. 2000).

The Pygmy Forest Community

In Mendocino County, patches of hydrophobic podsols exist on ancient uplifted marine terraces within the coast redwood forest (Waring and Major 1964; Zinke 1988; Sawyer et al. 2000). These highly acidic nutrient poor soils support the pygmy forest vegetation formation, populated by a suite of endemic species and scattered patches of stunted *S. sempervirens* (Westman 1975; Westman and Whittaker 1975; Northup et al. 1995). The ecotone between pygmy and redwood forest soils has been described as abrupt, with only few species tolerating the harsh pygmy forest conditions (Zinke 1988; Aitken and Libby 1994; Northup et al. 1998). Nevertheless, solitary redwood trees have been found occupying these infertile soils (Jenny 1973; Westman and Whittaker 1975; Sawyer et al. 2000).

Pygmy podsols are dominated by two endemic dwarf tree species; *Pinus contorta* ssp. *bolanderi* (Parl.) Critchf. (bolander pine) and *Hesperocyparis pygmaea* (Lemmon) Bartel (pygmy cypress). *Pinus muricata* D.Don (bishop pine) is common in a stunted form, and is accompanied by a number of Ericaceous shrubs including *Arctostaphylos nummularia* A.Gray ssp. *mendocinoensis* (P.V.Wells) V.T.Parker, M.C.Vasey and J.E.Keeley (pygmy manzanita), *Rhododendron macrophyllum* D.Don (coast rhododendron), *Rhododendron columbianum* (Piper) Harmaja (western Labrador tea), and *Gaultheria shallon* Pursh (salal) (Jenny 1973; Westman 1975; Westman and Whittaker 1975; Northup et al.1995). Jenny (1973) originally observed these species dominating the pygmy forest landscape, however, on rare occasions, a stunted "yellow-leafed struggling redwood tree" was found tolerating the nutrient-deficient soils.

Pygmy forest conditions developed on coastal terraces as a result of tectonic movements, wave activity, and fluctuation in sea levels during the Pleistocene period (Aitken and Libby 1994). The terraces increase in age with distance from the coast, with the oldest terraces, where pygmy forests, estimated at between 300,000 years of age (Merritts et al. 1991). The first terrace, closest to the ocean, is dominated by grassland with rich prairie mollisols (Jenny 1973). The second terrace is host to prolific stands of coast redwood (Aitken and Libby 1994). The third, fourth, and fifth terrace, where pygmy forests grow, are dominated by highly acidic podsols that have been weathered for millennia (Merritts et al. 1991). These soils are characterized by low pH, little organic matter, and hydrophobic tendencies. The A horizon in pygmy forests tends to be poorly developed and is often underlain by a distinctive ash-grey layer and an iron-stained clay layer known as "hardpan" which is found approximately 30 cm below the soil surface, and can severely limit root growth (Johnston 1994). The clay hardpan is extraordinarily impermeable; during winter rains prolonged flooding occurs and water drains slowly to lower terraces (Aitken and Libby 1994). In addition, pygmy soils are severely limited in available nutrients, such as phosphorus (P), potassium (K), and manganese (Mg), due to leaching over centuries in the presence of charged clay particles (Jenny 1973; Fox 1976; Walker and Syres 1976; Yu et al. 1999). Recent research suggests that P limitation may play a particularly important role in the formation of the pygmy community (Izquierdo et al. 2013). Pygmy forest soils do not provide productive growing conditions for *S. sempervirens*, and yet individuals of the species are able to survive within the community.

The concept of old-growth is commonly associated with productive forests and large trees. However, ancient stunted coast redwood trees have been observed in the proximity of the pygmy soil formation (Jenny 1973, Westman and Whittaker 1975). While forest composition, growth form, and crown structure of *S. sempervirens* have been studied extensively in productive stands, they have not been studied thoroughly in marginal sites, such as the pygmy forest ecotone. Our objectives were to characterize these features across a pygmy/old-growth redwood transition in order to expand the scope of understanding of what old-growth is by including a broader range of site conditions than past studies; and to determine if complex late-seral structural features exist on *S. sempervirens* growing in these marginal sites.

METHODS

Study site. Data were collected in the Russell Unit of Mendocino Headlands State Park approximately 1 km east of the Pacific Ocean, south of the town of Mendocino in Northern California, during the summer of 2012 (June-September). The area's average annual precipitation is approximately 99 cm, with an average temperature of 12.5° C (Northup et al. 1995). Though sections of the property were selectively logged in the late 19th and early 20th centuries, much of the site is dominated by old-growth, and mixed old-growth/second-growth stands. On the northwest portion of the property, old-growth gives way to pygmy forest, creating an ideal site to study this ecotone.

Study design and data collection. The transition between pygmy and old-growth redwood was divided into five strata (adapted from Westman and Whittaker 1975), including: 1) Extreme Pygmy (EP), dominated by endemic Ericaceous shrubs and conifers including *Arctostaphylos. nummularia* ssp. *mendocinoensis*, *Pinus contorta* ssp. *bolanderi*, and *Hesperocyparis. pygmaea*; 2) Short Pygmy (SP), an area with less stunted vegetation, but still dominated by pygmy forest associates; 3) Tall Pygmy (TP), an area dominated by pygmy forest associates, but with less dominance of pygmy endemics; 4) Transitional (T), with small single stem redwoods occurring as co-dominants *P. contorta* ssp. *bolanderi* and *H. pygmaea*; 5) Pygmy Redwoods (PR) dominated by stunted ancient redwoods, with rare occurrence of pygmy forest endemics.

We used a random sampling strategy to compare vegetation and soil between strata, and opportunistic sampling to characterize individuals of the target species (*S. sempervirens*) found within each stratum. A total of 50 (7 m diameter) sample plots were randomly located and stratified evenly across strata. Vegetation metrics recorded on each plot included: canopy cover (measured with a spherical densitometer); average crown height and maximum tree height (measured with a tape-measure); diameter at breast height (dbh) (or basal diameter for trees < 1.37 m height) of tree stems by species; number of stems; percent cover and height of shrub species; and percent cover herbaceous species.

Fourteen opportunistic samples were used to gather data on the growth form and structure of individual *S. sempervirens*, with the following metrics recorded: tree height, number of stems emerging from the root structure, diameter of largest stem, and presence of old-growth structural characteristics (large lateral branches, reiterated trunks, epiphytes, and fire hollows), and an estimate of crown complexity using the branch hierarchy method for trees with substantial crown structure (Van Pelt and Sillett 2008). Trees that were less than 3 m in height were accessed using an extension ladder. For trees larger than 3 m in height, the crown was accessed using International Society of Arboriculture climbing techniques. Prior to accessing the crown of a tree, assessments were made to ensure that disturbance to wildlife were minimized. Arboreal soil depth and volume was measured with a marked probe that was inserted into the surface of the substrate; with each measure averaged from three samples (Sillett and Van Pelt 2007). Epiphytic plants were identified to species.

To characterize soils, a soil sample of 450 ml was collected from each plot. The sample was taken 10 cm below true ground. The following soil properties were analyzed: percent of organic matter, phosphorus (Weak Bray and Sodium Bicarbonate-P), parts per million (ppm) of extractable cations (potassium, magnesium, calcium, sodium), hydrogen, sulfate-S (ppm), pH, cation exchange capacity (meq/100g), and percent cation saturation (computed). The soil analysis sample report with reference guide explanations from A & L Plains Labs, Inc. describe the weak Bray test, P1, as the most accurate for soils with low pH, and an ideal level of P is between 20ppm and 30ppm. Water-holding capacity was measured using a FieldScout TDR 200 (Spectrum Technologies, Inc., Painfield, Illinois. This device measures water-holding capacity by calculating the traveling time of an electromagnetic waveguide, which is dependent on the porosity and permeability of the soil. A marked 1 m probe was used to measure duff layer depth. In addition, four samples were taken from the A horizon with a soil auger on each randomly selected plot to estimate pH.

Statistical analysis. In order to detect changes across the ecotone, all possible ANOVAs comparing vegetation metrics and soil characteristics among the five strata were conducted, with Tukey HSD used for post-hoc mean separation. Pearson's Correlation Coefficient (r) was conducted as a preliminary test to measure independence between variables and shared variation. A correlation was considered strong if $r \geq 0.50$, or ≤ -0.50. The correlation was considered significant if $p < 0.05$. If the relationship was strong and significant, it was followed by a multiple stepwise linear regression analysis to obtain a predictive model. Two stepwise linear regression analyses were employed, one for "tree height" of redwoods and one for "stem diameter" of redwoods across all strata to build multivariate predictive models using each of 14 soil metrics as independent variables; and tree height and stem diameter as response variables. Additional simple linear regression analyses were used to identify the relationship between pH and biotic variables. Exploration of the growth form and crown structure of individual *S. sempervirens* specimens was primarily descriptive, with quantitative and qualitative comparisons made between samples. Features analyzed included branching patterns using the hierarchical system developed by Van Pelt and Sillett (2008), where the maximum number of features (main trunk, limbs, reiterated trunk, and branch) on a single limb

TABLE 1. MEAN VALUES OF VEGETATION AND SOIL CHARACTERISTICS MEASURED ACROSS A PYGMY/REDWOOD ECOTONE ON FIVE STRATA: EXTREME PYGMY (EP), SHORT PYGMY (SP), TALL PYGMY (TP), TRANSITIONAL (T), AND PYGMY REDWOOD (PR). Basal area was calculated from diameter (d) using $BA = \pi\ (½d)^2$. Within each row, strata sharing the same lower case letters did not exhibit significant differences based on single factor ANOVA analysis ($\alpha = 0.05$). Mean values for each metric below are reported with ±SE.

	EP	SP	TP	T	PR
Canopy height (m)	2.09^{a}	5.64^{b}	11.95^{c}	21.50^{d}	39.61^{e}
Canopy cover (%)	37.12^{a}	49.25^{b}	59.22^{b}	83.91^{c}	91.73^{d}
Shrub cover (%)	70.8^{a}	89.3^{b}	78.1^{b}	60.4^{c}	34.1^{d}
Herb cover (%)	1.8^{a}	1.3^{a}	3^{a}	0.4^{a}	2.35^{a}
Understory richness	6^{a}	10^{b}	10^{b}	10^{b}	15^{c}
Basal area (m^2/ha)	1429^{a}	1866^{a}	668^{b}	1094^{a}	3713^{c}
Basal area of *S. sempervirens* (m^2/ha)	$<0.01^{a}$	$<0.01^{a}$	$<0.01^{a}$	1019^{b}	3351^{c}
Basal area of *H. pygmaea* (m^2/ha)	1368^{a}	1752^{a}	611^{b}	33^{c}	0^{c}
pH	4.00^{a}	4.81^{b}	4.95^{b}	5.00^{b}	5.58^{c}
% Organic matter	3.52^{a}	2.90^{a}	3.96^{a}	6.63^{b}	10.13^{b}
% Water holding capacity	35.33^{a}	35.67^{a}	26.24^{b}	13.50^{c}	26.56^{b}
Cation exchange capacity (mEq/100g)	2.62^{a}	2.57^{a}	3.20^{a}	6.96^{b}	8.53^{c}
% cation saturation (K)	2.00^{a}	2.42^{a}	2.93^{a}	4.19^{b}	4.22^{b}
% cation saturation (Mg)	7.91^{a}	8.43^{a}	9.67^{b}	10.82^{c}	11.43^{c}
% cation saturation (Ca)	10.05^{a}	7.91^{a}	22.76^{b}	23.45^{b}	20.53^{b}
% cation saturation (Na)	3.12^{a}	2.83^{a}	4.67^{b}	4.67^{b}	4.90^{b}
P (weak bray) ppm	2.73^{a}	1.76^{a}	2.84^{a}	5.52^{b}	5.55^{b}

emerging from a redwood was calculated. Other features compared included the presence and absence of fire hollows, the number of stems emerging from a single root bole, and the presence of above ground versus below ground root structures. All statistical analysis was conducted using SPSS software (IBM Corp. Version 19.0. Armonk, NY)

RESULTS

Soil characteristics, vegetation, and the size and growth-form of *Sequoia sempervirens*, varied significantly across the pygmy/redwood ecotone. Analysis of variance indicated that mean soil properties were significantly different among strata (Table 1). Nutrient availability was generally below what is considered ideal for normal soils, and pH ranged from 4.0 to 5.8, with the most acidic soils found in the "extreme pygmy" stratum. Potassium, calcium, and phosphorus exhibited the lowest measures where pygmy vegetation was most pervasive. A similar pattern was observed for organic matter and CEC. Water holding capacity did not exhibit significant variation in relationship to the ecotone strata.

Vegetation composition and structure also exhibited significant variation among strata (Table 1). Canopy height and canopy cover were relatively low on the most extreme pygmy soils, while shrub cover was relatively high. Herbaceous cover was uniformly low across the ecotone except for the "pygmy redwood" stratum, where it was significantly higher. *Hesperocyparis pygmaea* and *Pinus contorta* ssp. *bolanderi* had the highest relative dominance on first three strata, and *S. sempervirens* and *Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii* on the last three strata (Fig. 1). The presence of *P. menziesii* in the tall pygmy (TP) stratum and *H. pygmaea* in the transitional (T) stratum suggests a somewhat porous boundary between the two communities. Variation was also found in understory species across the ecotone. Both herbaceous cover and richness of understory species were significantly higher in "pygmy redwood" compared to all other strata. There were, however, a number of species that were limited to pygmy soils including two California Native Plant Society listed species, *Arctostaphylos nummularia* ssp. *mendocinoensis* and *Lilium maritimum* Kellogg (coast lily) (Table 2).

Pearson's correlations indicated that basal area of *S. sempervirens* on targeted plots had a significant positive association with phosphorous ($r = 0.517$, $P = 0.02$), potassium ($r = 0.761$, $P < 0.001$), calcium ($r = 0.619$, $P = 0.005$), CEC ($r = 0.726$, $P < 0.001$), and sodium ($r = 0.523$, $P = 0.049$). In addition, significant associations were found between tree height and phosphorous ($r = 0.553$, $P = 0.013$), potassium ($r = 0.677$, $P = 0.002$), calcium ($r = 0.598$, $P = 0.007$), and CEC ($r = 0.666$, $P = 0.002$).

Multivariate analysis, using stepwise regression, resulted in a strong predictive model ($P < 0.001$; $R^2 = 0.724$) for stem diameter, with CEC ($P < 0.001$) and P ($P = 0.002$) as the strongest predictors (diameter = - 0.290 + 0.135 CEC + 0.113 P ppm). A model was also developed for tree height ($p = 0.002$; $R^2 = 0.578$), with K ($P < 0.001$) and P ($P = 0.004$) as predictors (height = 15.452 + 0.262 K ppm + 0.493 P ppm). Models for other vegetation metrics did not yield significant results. While pH did not emerge as a strong predictive variable, simple linear regression indicated that several biotic metrics were positively correlated with soil pH (Table 3); including canopy cover, canopy height, herbaceous cover, understory richness, total basal area, and the basal area of *S. sempervirens*. Soil pH was negatively

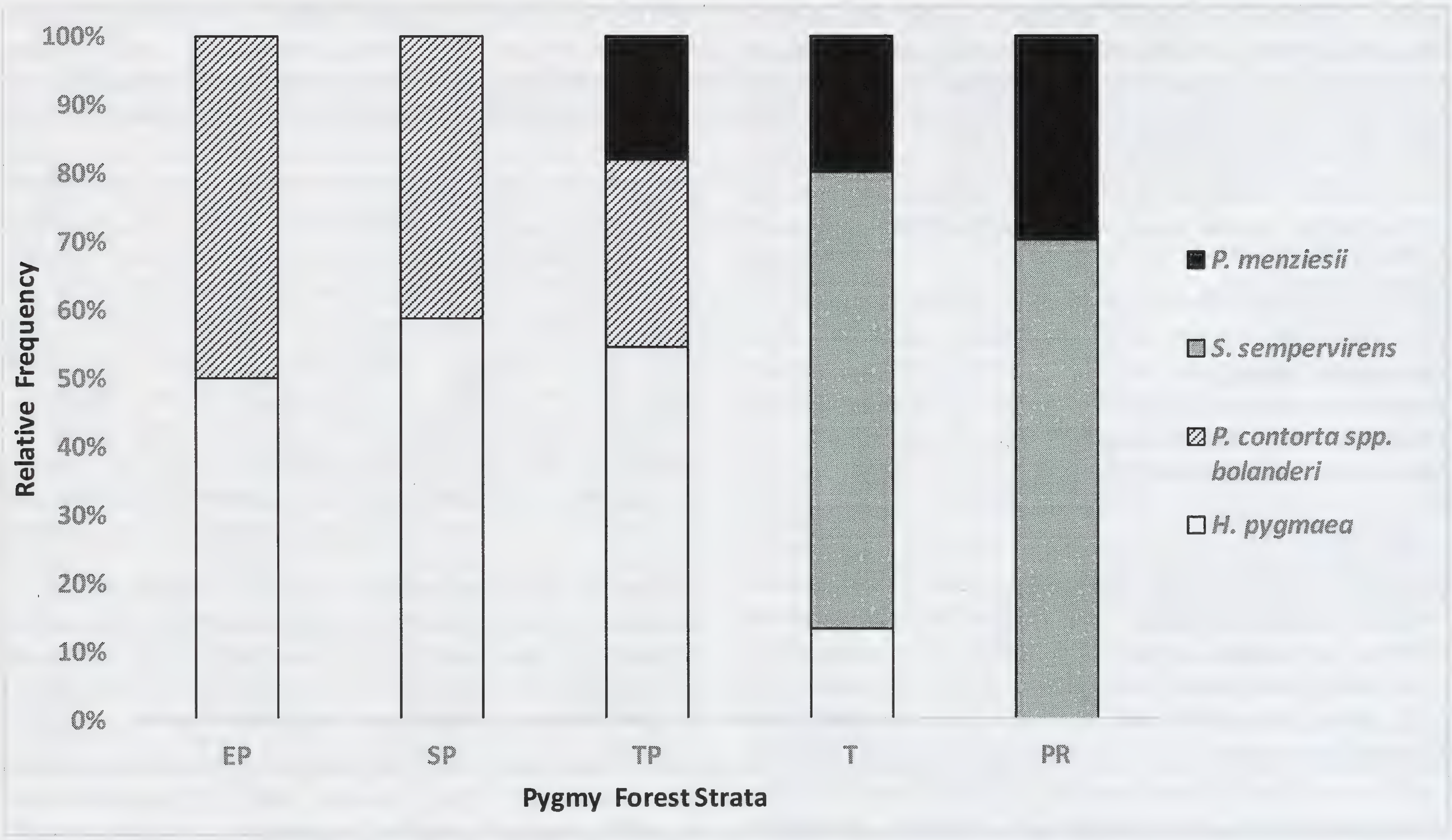

FIG. 1. Relative frequency of the four most commonly occurring tree species across a pygmy redwood forest ecotone on five strata: extreme pygmy (EP), short pygmy (SP), tall pygmy (TP), transitional (T), and pygmy redwood (PR).

correlated with shrub cover and basal area of *H. pygmaea*.

Growth Form and Structure

Qualitative analysis of the growth-form of *S. sempervirens* across the pygmy/redwood ecotone indicated notable variation among strata (Table 4). Redwood trees were stunted, multi-stemmed, and shrub-like close to the center of the pygmy formation, but exhibited more upright forms closer to the ecotone. A total of 312 epiphytic plants were observed growing on *S. sempervirens* in the "tall pygmy," "transitional," and "pygmy redwood"

TABLE 2. MEAN PERCENT COVER OF UNDERSTORY SHRUBS AND HERBACEOUS SPECIES OCCURRING ON A PYGMY/REDWOOD FOREST ECOTONE ACROSS FIVE STRATA: EXTREME PYGMY (EP), SHORT PYGMY (SP), TALL PYGMY (TP), TRANSITIONAL (T), AND PYGMY REDWOOD (PR).

Species	Family	EP	SP	TP	T	PR
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	5.4	3.4	1.8	0.9	1.5
Polystichum munitum (Kaulf.) C. Presl	Dryopteridaceae	0	0	0	0	0.3
Arctostaphylos columbiana Piper	Ericaceae	0	0	0.3	0	0
Arctostaphylos nummularia ssp. *mendocinoensis*	Ericaceae	0	0.2	0.2	0	0
Chimaphila menziesii (D. Don) Sprengel	Ericaceae	0	0	0	0.1	0
Gaultheria shallon	Ericaceae	8.9	8.9	9.4	7.5	9.5
Rhododendron columbianum	Ericaceae	24.5	46	4.5	0	0
Rhododendron macrophyllum	Ericaceae	3.5	4.2	29.5	13.1	4.6
Vaccinium ovatum	Ericaceae	23.7	25.3	27	32.5	5.6
Vaccinium parvifolium Sm.	Ericaceae	0	0.1	1.7	1.1	1.2
Chrysolepis chrysophylla (Hook.) Hjelmq.	Fagaceae	0	0	1.6	0	0
Clintonia andrewsiana Torr.	Liliaceae	0	0	0	0	0.5
Lilium maritimum	Liliaceae	0	0.1	0	0	0
Trillium ovatum	Melanthiaceae	0	0	0	0.1	0.7
Claytonia sibirica L.	Montiaceae	0	0.1	0	0	0.1
Morella californica (Cham.) Wilbur	Myricaceae	5.6	3.8	4.2	6.2	8.7
Lysimachia latifolia (Hook.) Cholewa	Myrsinaceae	0	0	0	0	0.1
Calypso bulbosa	Orchidaceae	0	0	0	0.1	0.25
Goodyera oblongifolia	Orchidaceae	0	0	0	0.1	0.2
Polypodium scouleri	Polypodiaceae	0	0	0	0	0.5
Viola sempervirens E. Greene	Violaceae	0	0	0	0	0.1

TABLE 3. LINEAR REGRESSION BETWEEN SOIL pH AND EIGHT RESPONSE VARIABLES ACROSS A PYGMY/OLD GROWTH REDWOOD ECOTONE. Basal area was calculated from diameter (d) using $BA = \pi (\frac{1}{2}d)^2$.

	Coefficient	R^2	P-value
Canopy height (m)	+ 0.015	0.29	< 0.001
Canopy cover (%)	+ 0.011	0.25	< 0.001
Shrub cover (%)	− 0.008	0.23	0.003
Herb cover (%)	+ 0.052	0.34	< 0.001
Understory richness	+ 0.023	0.27	< 0.001
Basal area (m^2/ha)	+ 0.027	0.33	< 0.001
Basal area of *S. sempervirens* (m^2/ha)	+ 0.035	0.41	< 0.001
Basal area of *H. pygmaea*	− 0.020	0.35	< 0.001

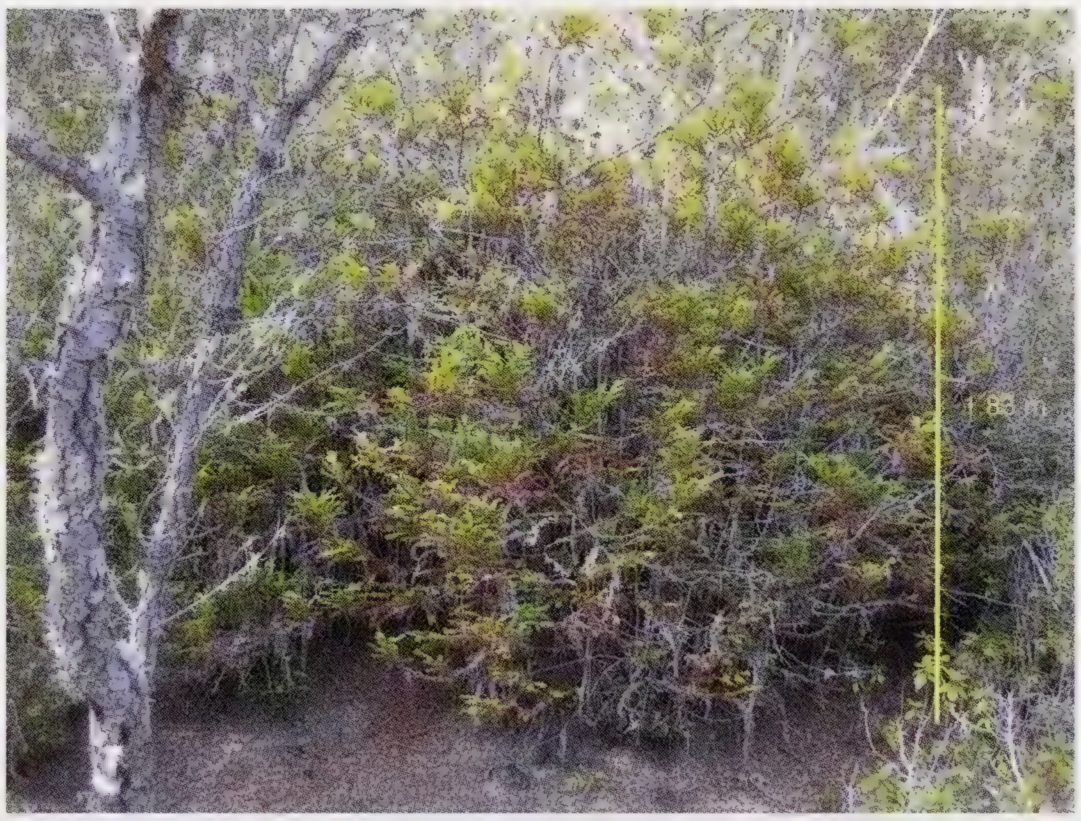

FIG. 2. A stunted shrub-like specimen of *S. sempervirens* with clustered 338 stems located in the extreme pygmy (EP) stratum of the pygmy/redwood ecotone.

strata including *Gaultheria shallon*, *Polypodium scouleri* , and *Vaccinium ovatum*. Fire hollows and complex canopy features of substantial size (> 12 cm diameter) were found exclusively in the "transitional" and "pygmy redwood" strata.

Variation among individual *S. sempervirens* with respect to growth form was observed within strata as well. In the "extreme pygmy" one highly clustered individual with small yellowed leaves (EP-1) and 338 stems (0.01–1.83 m in height; maximum of 2 cm basal diameter) occupied space of 4.86 m^2 and originated from an above ground root bole (Fig. 2). Two other individuals (EP-2 and EP-3) were less tightly clustered, with fewer stems (16 and 37 respectively). The stems for EP-2 and 3 were taller (maximum 2.49 m) and greater in basal diameter (maximum 7 cm) than those observed for EP-1. In addition, the individual stems of EP-1 all originated from underground root systems, rather than an above ground root bole, and included co-dominance and miniature lateral branching structures.

Trees within the "short pygmy" stratum were highly variable in terms of size and structure. SP-1 consisted of a single tree with two clonal stems originating at the base, and a total height of 9.2 m and a dbh of 16.26 cm. SP-2 included a single root bole with eleven stems originating at the burl, with the tallest stem measured at 5.2 m with a dbh of 22.1 cm. SP-3 included 124 stems within an area of 20.6 m^2. The largest stem had a maximum dbh of 34 cm, and had a total height of 8.8 m.

The "tall pygmy stratum" was characterized by islands of redwoods growing within a sea of pygmy dominants. TP-1 included ninety-one stems and occupied approximately 32.09 m^2. The maximum height measured was 10.85 m, with a dbh of 34 cm. A single epiphytic *G. shallon* was observed growing out of the trunk of a tree, 38 cm above ground. TP-2 included ninety-nine stems within an area of approximately 18.18 m^2. The tallest stem measured 5.89 m in height and had a dbh of 10 cm. TP-3 included 82 stems within an area of 18.7 m^2. The tallest tree measured 12.1 m and had a dbh of 37.85 cm. This individual had a broken top and two reiterations above 3 m. Fire marks were present at the base of the tree, and there were five *P. scouleri* established on the decaying top.

The "transitional stratum" included three samples. Two of these samples included trees with measurable complex crown features. T-1 was characterized by three intertwined clonal stems with heights observed at 20.45 m, 28.35 m, and 38.15 m; and dbh of 133 cm, 176 cm, and 240 cm. Two of the stems had fire hollows with a volume of 0.56 m^3 and 1.21 m^3 respectively. The maximum crown complexity observed in this stratum was five, resulting from 40.13 cm diameter lateral branch growing off of the largest (T1) stem, with hierarchical order BRRLT (where B = branch; R = reiterated trunk; L = limb; and T = main trunk). Twenty-five *P. scouleri* were observed growing as epiphytes on the largest and smallest stems. T-2 included eight stems within an area of 54.06 m^2. The structure of the trees in this plot had an umbrella like appearance. Where the tops had not

TABLE 4. OLD-GROWTH CHARACTERISTICS OBSERVED ON A PYGMY/REDWOOD ECOTONE ACROSS FIVE STRATA; EXTREME PYGMY (EP), SHORT PYGMY (SP), TALL PYGMY (TP), TRANSITIONAL (T), AND PYGMY REDWOOD (PR). Dashes indicate listed data type was not observed.

	EP	SP	TP	T	PR
Maximum crown complexity order	-	-	-	5	8
Maximum fire hollow volume	-	-	-	1.21 m^3	10 m^3
Number of epiphytes observed	-	-	6	44	264
Epiphyte species observed	-	-	*G. shallon* *P. scouleri*	*P. scouleri*	*P. scouleri* *V. ovatum*

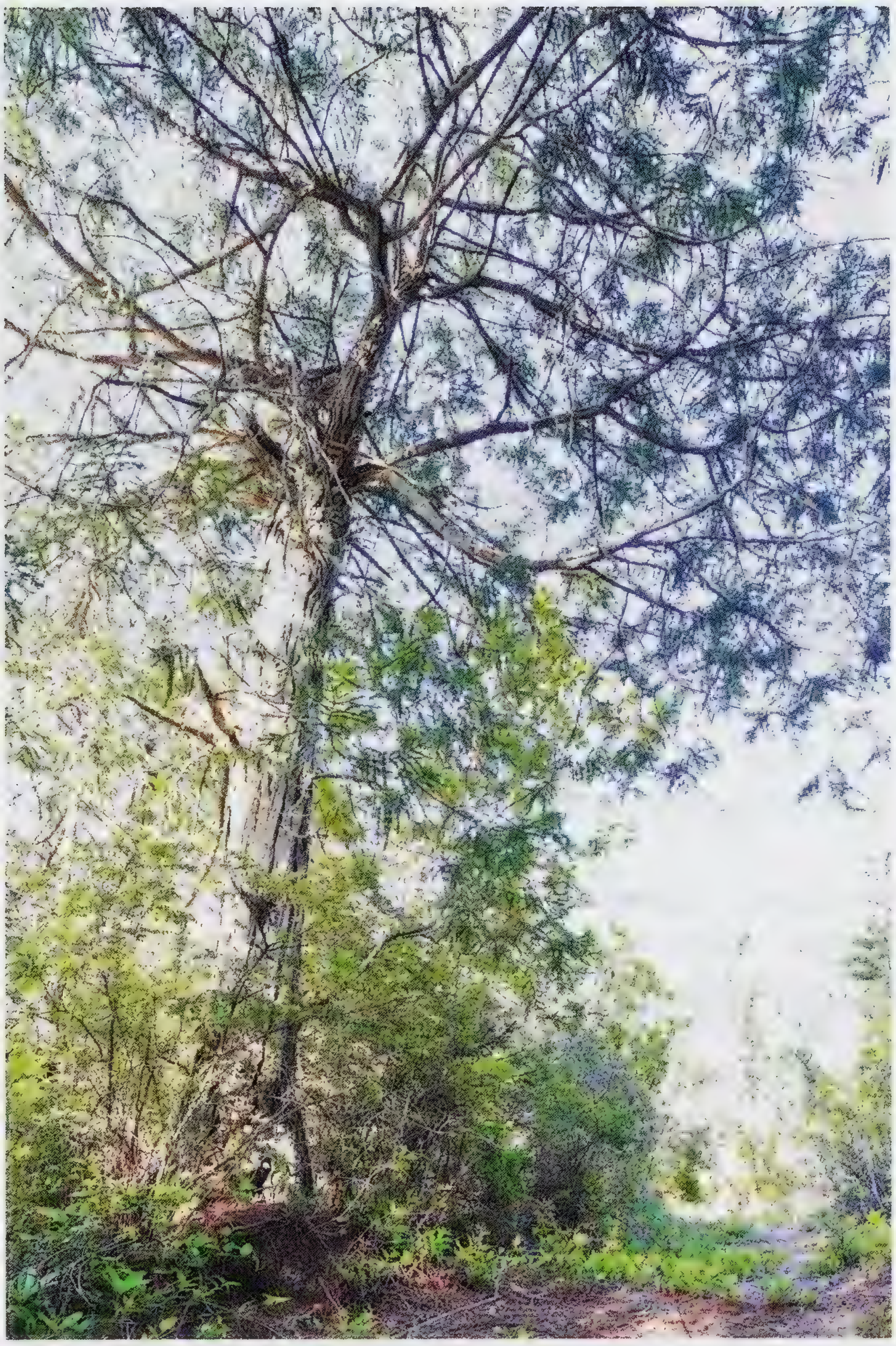

FIG. 3. A single stem *S. sempervirens,* 7.4 m in height, with complex crown features located in the transitional stratum (T) of the pygmy/redwood ecotone. Photo courtesy of Dylan Crutchfield, Department of Environmental Studies, San Jose State University.

been broken off, but the growth was somewhat decurrent. The largest stem had a height of 17.50 m and a dbh of 105 cm. Fifteen *P. scouleri* individuals were observed on two of the stems with 14 individuals recorded on the largest stem. A single fire hollow was also observed on this tree with a volume of 0.48 m^3. T-3, measured 7.4 m in height, and had a dbh of 58 cm (Fig. 3). A maximum crown complexity index of three was observed for T-3 on a 24.89 cm lateral branch with a hierarchical order of (BRT).

The "pygmy redwood" stratum included four samples, all of which exhibited old-growth characteristics including fire hollows, complex crown structure, and colonization by epiphytic plants. The first tree sampled (PR-1) grew as part of an eight stem clonal grouping, and was 26.1 m tall with a dbh of 230 cm. Extensive fire damage to the main stem resulted in a large fire hollow at the base, with a volume of approximately 8 m^3 and an internal height of 6.33 m. PR-1 had a total of 41 structural characteristics, with basal diameter of 66 cm or greater at the trunk, and one major reiteration with a diameter of 40.6 cm. PR-1 had a maximum crown complexity order of eight on the 40.6 cm diameter reiteration with a hierarchy of (BRLRLRLT). A total of 262 epiphytic *P. scouleri* and 12 *V. ovatum* were observed growing on decaying limbs and crotches. The largest fern mat had an area of 98 cm^2, with 0.09 m^3 arboreal soil. PR-2 was a single stem 33.46 m high with a dbh of 1.42 m. This tree had a bifurcated top with two reiterations originating 3 m below where a decayed former apical stem was observed. PR-2 had a maximum crown complexity

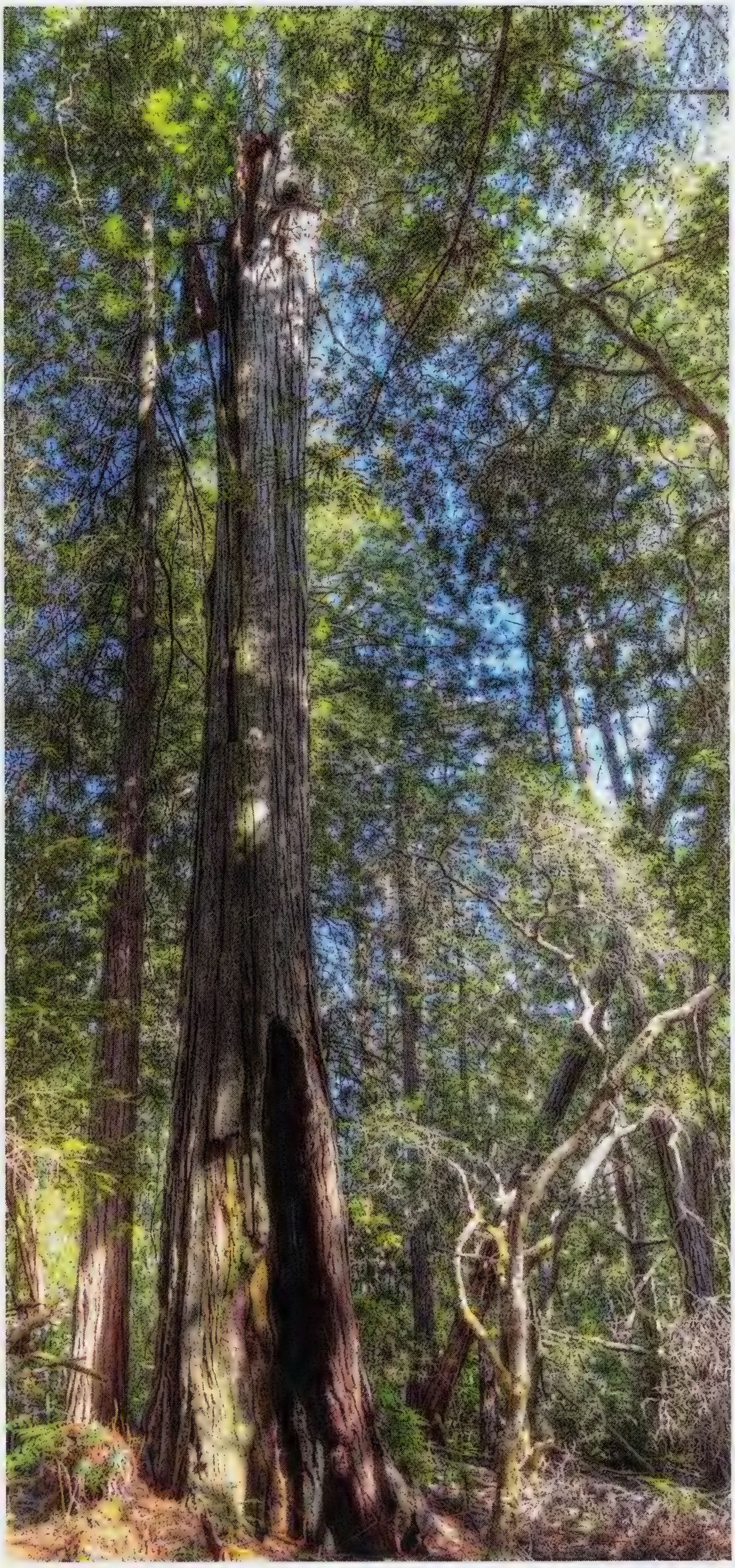

FIG. 4. A stunted ancient redwood (PR-3) found in the pygmy redwood' strata with a height of 27.43 m. A continuous fire hollow ran from top to bottom, and was a nesting site for *Tyto alba* (barn owls). Photo courtesy of Dylan Crutchfield, Department of Environmental Studies, San Jose State University.

order of six on a 25.16 cm diameter lateral branch with a hierarchy of (BRLRLT). Two epiphytic *P. scouleri* were found on a live limb. PR-3 (Fig. 4), had a total height of 27.43 m and dbh of 157 cm. The maximum crown complexity order for PR-3 was seven on a 78.11 lateral branch with a hierarchy of (BRLRRLT). The main stem had been significantly damaged by fire so that the trunk was almost entirely hollow. A fire cave originated at the bottom and extended to a height 12.8 m, with an estimated volume of 10 m^3. This hollow was a nesting site for barn owls (*Tyto alba*), based on personal observation of the owl leaving the hollow, as well as a proliferation of owl pellets around the base of the tree. The owl tree included one main reiteration 14.62 m from the ground, and 52 epiphytic *P. scouleri*. PR-4 consisted of two clones originating at the same basal point. The largest clone had a height of 35.1 m and a dbh of 1.59 m. A fire hollow measured 0.31 m^3, with an internal height of 2.73 m. Several large reiterations were observed (two larger that 80 cm in diameter, and six between 18-34 cm). PR-4 had a maximum crown complexity order of seven on a 34.04 cm diameter reiteration with a hierarchy of (BRLLRRLT).

Discussion

The stunted *S. semprevirens* trees found on the edge of the pygmy soil formation exhibited complex crown features, fire caves, and epiphytic plant associations, supporting the theory that forests need not produce large trees in order to provide the habitat features associated with old-growth (Wardle 1993). Stress response and disturbance history is likely the primary factor determining structural complexity, rather than tree size or stand density.

Characterization of soils across the ecotone supported previous research, and indicated that particular soil conditions were associated with vegetation structure and composition (Jenny 1973; Westman and Whittaker 1975; Brady 1990; Yu et al. 1999). As expected, pH and the availability of nutrients (P, K, Ca, and Na) were positively correlated with tree size and a variety of other floristic parameters (Table 1, Fig. 1), in agreement with the conclusions of previous investigations (Northup et al. 1998; Yu et al. 1999). In addition, multivariate analysis supported the theory that phosphorus limitation plays a crucial role in predicting the structure and composition of pygmy vegetation (Izquierdo et al. 2013).

A variety of floristic patterns emerged across the pygmy/redwood ecotone as well. The dominance of the pygmy endemic tree species (*Hesperocyparis pygmaea* and *Pinus contorta* ssp. *bolanderi*) was greatest in the "extreme pygmy" stratum, as was the cover of pygmy associated Ericaceous shrubs *Arctostaphylos nummularia* ssp. *mendocinoensis* and *Rhododendron columbianum*. Ericaceous generalists (*Rhododendron macrophyllum* and *Vaccinium ovatum*) exhibited no preference for either habitat type, and a number of redwood associated herbaceous species (Mahony and Stuart 2000) were observed exclusively in the redwood-dominated strata (*Calypso bulbosa* (L.) Oakes, *Clintonia andrewsiana* Torrey, *Goodyera oblongifolia* Raf., *Polypodium scouleri*, and *Trillium ovatum* Pursh). The sensitivity of redwood-associated understory species to pygmy soil conditions is likely a result of intolerance to lack of shade from overstory canopy and poor nutrient availability resulting from low soil pH (Northup et al. 1998), with the possibility of mycorrhizal relationships being affected as well (Wurzburger and Bledsoe 2001).

Three essential growth-forms of *S. sempervirens* were observed: a multi-stemmed shrub-like form; a vertical, highly stunted sub-canopy form; and a tall vertical co-dominant form with complex canopy structure. *Sequoia sempervirens* was able to manifest these multiple growth-forms as a result of prolific basal and epicormic sprouting (Ishii et al. 2002; Douhovnikoff et al. 2004; Van Pelt et al. 2016). Sprouting in *S. sempervirens* is a stress response, and where the stresses are unremitting, sprouting is continuous. The multi-stemmed shrub-like form of *S. sempervirens* is essentially a mass of basal sprouts emerging from a single half buried lignotuber. Each sprout strives to assert itself, but water and nutrient availability are limited to the point where no sprout can develop apical dominance. On more productive sites where the type and magnitude of stressors are stochastic in nature, epicormic sprouting plays its part in the development of crown complexity. Mechanical damage resulting from an adjacent tree-fall or lighting strike, or physiological damage from a freeze or prolonged drought, can trigger a sprouting response in the canopy, resulting in the production of trunk reiterations and unusual branching patterns.

There is a tendency to think of old-growth *S. sempervirens* forests as uniformly impressive in terms of stature, but as these results indicate, redwoods are highly variable in terms of growth form. Old-growth, as defined by management history (Peterken 1996), can also include ancient dwarfed trees growing on soils with low nutrient availability. These stunted redwoods, that grow at the edge of the species' ecological tolerance, may provide insight into the future of *S. sempervirens*. With changes in climate predicted over the coming decades, a growing proportion of the range may be relegated to poor site conditions (Johnstone and Dawson 2010).

The most noteworthy finding of this study was the extent of old-growth forest features observed on trees within the influence of pygmy soils. Complex crown structures and extensive fire hollows were discovered on stunted trees growing on marginal soils within the "transitional" and "pygmy redwood" strata, and epiphytic relationships existed even deeper into the pygmy forest formation with *P. scouleri* thriving on the decaying to top of a small redwood in the "tall pygmy" strata. These results support findings from other forest types as well, suggesting that the growth form of trees was the result of repeated disturbances rather than size or age (Fahey et al. 2015; Wardle 1993).

ACKNOWLEDGEMENTS

This project was supported by the Mendocino Institute and the California Department of Parks and Recreation. The project would not have been possible without the expertise of Gregory Eugene McKenna, who served as a climbing mentor for the canopy team, provided equipment, and spent countless hours in the tree crowns. Matthew Lambert also provided invaluable assistance by serving as a climbing partner and data collector. Special gratitude goes to Lou and "Skilly" Russell who protected this unique site from the hands of loggers to preserved in perpetuity.

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MADROÑO, Vol. 66, No. 1, pp. 24–29, 2019

A NEW JEWELFLOWER (*STREPTANTHUS*, BRASSICACEAE) FROM MARIN COUNTY, CALIFORNIA, USA

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ABSTRACT

Streptanthus anomalus D.L.Smith, A.Arthur, & R.E.Preston is a newly described species growing on serpentine soils in the vicinity of Mount Burdell in Marin County, CA. Floral morphology and other characters indicate that this taxon is most closely related to the *S. glandulosus* complex, but the bracted inflorescence is unlike that found in any other member of that complex. This very rare serpentine endemic, restricted to two known populations, merits recognition as a species of conservation concern.

Key Words: California, endemism, floristics, rare species, serpentine, taxonomy.

The genus *Streptanthus* Nutt. currently consists of about 35 species in western North America, with the primary center of diversity in California (Al-Shehbaz 2010), although the circumscription of infrageneric and intraspecific taxa is likely to change in the near future as new findings based on DNA data become available (Cacho et al. 2014). The genus is well-known as the subject of many ecological studies, especially with respect to edaphic endemism (Kruckeberg 1951; Reeves et al. 1981; Boyd et al. 1994; Strauss and Cacho 2013). The common name "jewelflower" stems from the brightly colored sepals, which vary among species from green, to bright yellow, to white, to pink, to a deep reddish-purple.

In May 2011, during a rare plant survey of a property in Marin County, Aaron Arthur encountered a jewelflower population with wine-red sepals that initially struck him as possibly one of several subspecies of *Streptanthus glandulosus* Hook. that occur in that region. However, the plants did not key well using The Jepson Manual (Buck et al. 1993), Marin Flora (Howell et al. 2007), or A Flora of Sonoma County (Best et al. 1996) and individuals did not fit the taxonomic descriptions in The Jepson Manual.

In May 2012, Doreen Smith also encountered an unfamiliar jewelflower in the same general area, although these plants had yellow sepals. Plants in both populations were characterized by deep yellow, ovate leaves and bracts that stood out distinctly from the surrounding grassland. Because the most distal bracts subtended the proximal one or two flowers, the plants most closely resembled *S. tortuosus* Kellogg and keyed fairly well to that species in most recent treatments of *Streptanthus* (Rollins 1993; Buck et al. 1993; Al-Shehbaz 2010, 2012).

The authors sent photographs to several *Streptanthus* authorities for help with identifying the plants, and the general consensus was that these populations had characteristics of both *S. tortuosus* and *S. glandulosus* and probably represented an unusual form of *S. tortuosus*. However, photographs of the plants posted online as *S. tortuosus* at the CalPhotos website (https://calphotos.berkeley.edu/flora/) came to the attention of the lead author, who immediately recognized that the plants were not *S. tortuosus*, based on his extensive experience with the floral morphology and pollination biology of that species (Preston 1991, 1994). A subsequent visit to one of the populations confirmed that this was a distinctive new taxon, and samples of the flowers, leaves, and seeds were collected for further analysis. Dissection of the flowers indicates that the plants are closely related to members of *Streptanthus* section *Euclisia* Kruckeberg and Morrison, which consists of *S. glandulosus* and its multiple subspecies. Members of section *Euclisia* have carinate sepals, upper stamens with connate filaments (filaments of lower stamens not connate) and much smaller or sterile anthers, a round, flat stigma, and flattened siliques that are glabrous or hispid. Because the bracted inflorescence is unique among section *Euclisia*, the new taxon is recognized at species rank.

This remarkable new species, growing in close proximity to a large suburban population and in a well-traveled area, adds to the growing list of floristic surprises found "in our backyards" (Ertter 2000).

TAXONOMIC TREATMENT

Streptanthus anomalus D.L.Smith, A.Arthur, & R.E.Preston, sp. nov. (Figs. 13).—Type: USA, California, Marin Co., Mt. Burdell, County open space, 25 May 2015, *Doreen L. Smith s.n.* (holotype: CAS1202615).

Allied with *Streptanthus glandulosus* Hook., but differs by having conspicuous ovate, deeply clasping distal leaves that bract the inflorescence below or above the proximal flower.

Plants annual. **Stems** erect, simple to branched, lower stems and leaves with stiff, bulb-based hairs, reddish-tinged, 1.5–4.0(–6) dm tall. **Leaves** rosetted basally, basal blades oblanceolate, dentate, margins ciliate, faces with scattered short, stiff hairs, 3–5 cm long; proximal cauline leaves clasping, oblong, dentate, margins ciliate, 3–4 cm long; basal and lower cauline leaves generally deciduous by flowering; distal leaves deeply clasping, ovate, entire to distally dentate, glabrous, turning yellow by flowering, 1–2.5 cm long, 0.5–2 cm wide. **Flowers** divaricately ascending to horizontally spreading, ± secund, pedicels 2–3 mm long. **Sepals** yellow or purple, medially keeled, tips obtuse, erect, glabrous or with short bristles, 6 mm long. **Petals** exserted, base yellow, blades brown to purple with white margins, 7–9 mm long. **Stamens** in three unequal pairs, ± exserted, anthers of the lateral stamens larger than those of the lower stamens, upper stamens with fused filaments, sterile anthers. **Siliques** straight to arcuate, glabrous or with sparse, short, stiff bristles, 4–7 cm long, 3–4 mm wide. **Seeds** 30–40, 2 mm long, 1.75 mm wide, narrowly winged all around.

Paratypes: USA, California, **Marin Co.**, San Antonio Creek watershed, north side of greater Mt. Burdell Ridge, 07 Aug 2011, *A. Arthur 10* (CAS1204602); Mt. Burdell Open Space, 21 June 2015, *R. E. Preston 3006* (DAV). [Note: We were unable to locate any prior or additional specimens.]

ETYMOLOGY

The specific epithet "anomalus" alludes to the anomalous possession of bracted inflorescences that led to the initial hypothesis that this was an odd form of *S. tortuosus*. We suggest "Mount Burdell jewelflower" as the common name for this species.

PHENOLOGY AND REPRODUCTIVE BIOLOGY

Streptanthus anomalus is an annual species that germinates in response to winter rains and forms rosettes during the early spring. The plants bloom from mid-May through mid-June. Sepal color is polymorphic, being wine-red in one population and bright yellow in the other population (Fig. 2). Sepal color is generally uniform within *Streptanthus* populations, but in some species, sepal color can vary among subspecies or even among populations (Hoffman 1952; Kruckeberg 1957a; Kruckeberg et al. 1982; Kruckeberg and Morrison 1983; Dolan and LaPré 1989; Boyd et al. 2009; Mayer and Beseda 2010). Leaf morphology changes substantially as the plants develop (Figs. 1, 3). The basal rosette leaves are sessile, oblong, with dentate margins, and hirsute with bulb-based trichomes. Leaves developing distally become oblong, are clasping at the base, and are less hairy than basal leaves. The upper leaves are ovate, deeply clasping, with entire to dentate margins, and are glabrous. The leaf teeth are often tipped with orange hydathodes, which contrast strongly with the dark green of the leaves. These colored structures are found in other serpentine-endemic *Streptanthus* species and appear to be egg-mimics of Pierid butterflies that reduce the level of oviposition and subsequent herbivory (Shapiro 1981).

Streptanthus species are self-compatible, but predominantly outcrossing, requiring pollinator visits for seed set due to a combination of protandry and spatial separation of the anthers and stigmas (Rollins 1963; Preston 1991, 1994; Dieringer 1991). In *S. anomalus*, however, the sepals, petals, and stamens remain erect, so that there is relatively little spatial separation of the anthers and stigmas (Fig. 2), which may indicate some level of self-pollination. Kruckeberg (1957b) reported a similar floral morphology for *S. glandulosus* subsp. *niger* (Greene) Al-Shehbaz, M.S.Mayer & D.W.Taylor, observing that the anthers remain included in the mouth of the corolla, so that the stigma picks up pollen from them as the pistil elongates, and concluding that the flowers were self-pollinating. Unopened flowers (n = 7) and mature siliques (n = 29) were collected in the field on June 21, 2015 (vouchered by *Preston 3006*). Pollen counts were determined following the methods in Preston (1985), and ovule and seed number were determined from dissection of the siliques. The lateral anthers of *S. anomalus* average 37,533 pollen grains per anther, and the lower anthers average 16,000 pollen grains per anther, for a total of 107,066 pollen grains per flower. With an average of 35.3 ovules per ovary, the pollen-ovule ratio is 3,033, which is at the low end of the range for allogamous species in the Brassicaceae and comparable to that for *S. glandulosus* (3,800) (Preston 1985). Strongly outcrossing species in the family, such as *Streptanthus tortuosus,* have a much higher pollen-ovule ratio (5,000–10,000) than *S. anomalous* (Preston 1985; 1994). Seed set in *S. anomalus* was relatively high (mean = 84.9%, range = 55.4–100%). By contrast, seed set in open-pollinated *S. tortuosus* populations averaged 70.7% (range = 61.7–77.3%, six populations) (R. Preston, unpublished data).

DISTRIBUTION AND ECOLOGY

Streptanthus anomalus is known from only two small populations in the vicinity of Mount Burdell, in Marin County. The plants grow in grassy openings in

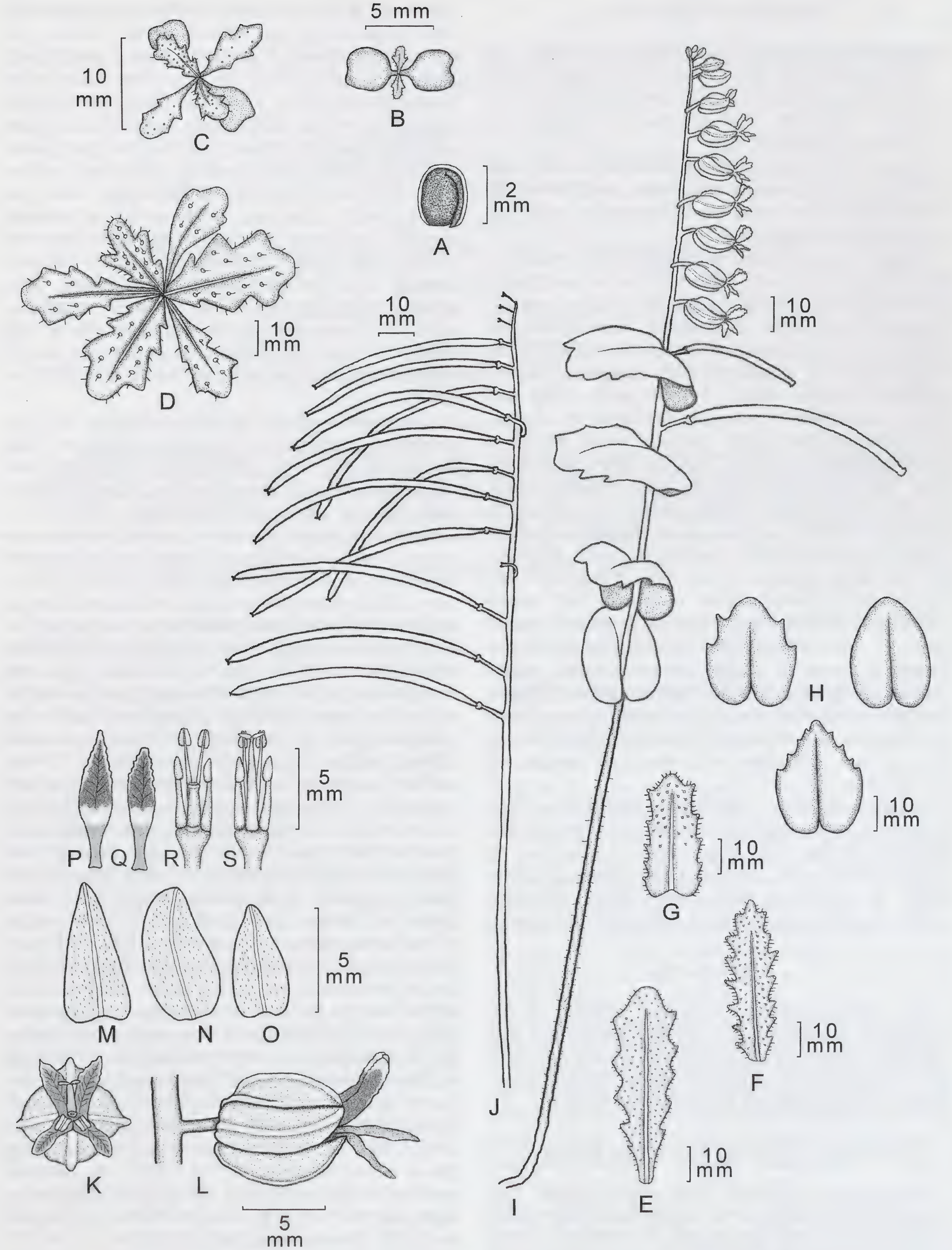

FIG. 1. Illustration of *Streptanthus anomalus*. A. Mature seed with narrow wing. B–C. Seedlings. B. Cotyledons and first leaves. C. Four-leaf stage. D. Basal leaf rosette. E–H. Stem leaves. E. Basal leaf. F. Lower cauline leaf. G. Upper cauline leaf. H. Bracting leaves, showing leaf margin variation. I. Habit at anthesis. J. Mature siliques. K–J. Flower at anthesis. K. Frontal view. L. Lateral view. Sepals. M. Abaxial sepal. N. Lateral sepal. O. Adaxial sepal. P–Q. Petals. P. Adaxial petal. Q. Abaxial petal. R–S. Stamens. R. Adaxial stamens removed to show ovary. S. Adaxial view of stamens showing connate adaxial stamens with vestigial anthers. From live material, vouchered by *Preston 3006*.

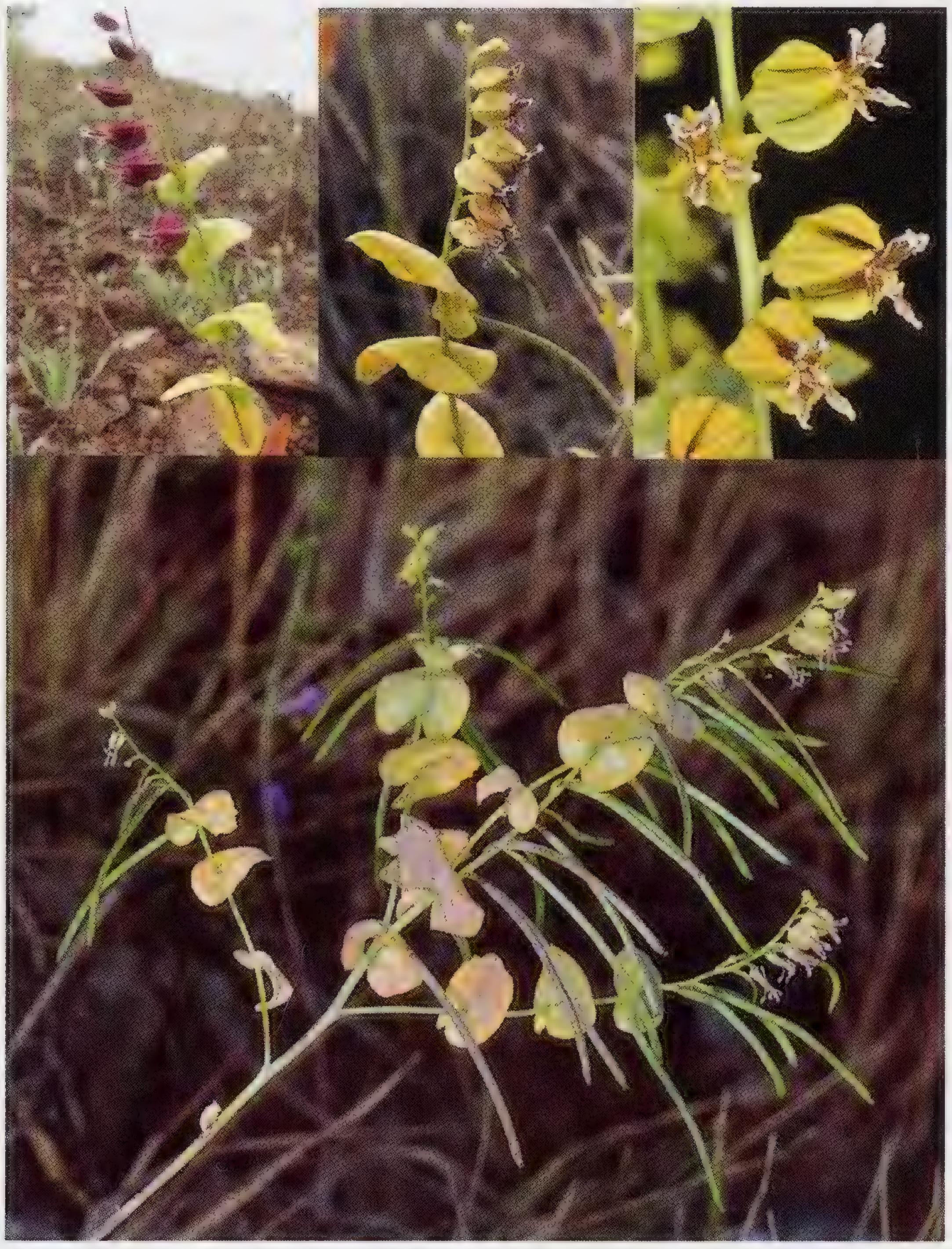

FIG. 2. Inflorescence, flowers, and fruits of *Streptanthus anomalus*. Upper left: wine-red-flowered morph. Upper middle: yellow-flowered morph. Upper right: close-up of flowers, showing the relative position of petals, anthers, and the stigma. Lower: inflorescence, showing the bracts and developing siliques.

oak woodlands (Fig. 4) on serpentine soils, between 50 and 115 m in elevation. The ridgeline supporting the northern population is mapped as Henneke stony clay loam (Kashiwagi 1985). These soils are dark rocky clays, formed from residuum weathered from serpentinite. The soil supporting the southern population is mapped as Montara clay loam, which also formed in material weathered from serpentinitic rocks (Kashiwagi 1985). Both soils are shallow, only 20 to 50 cm deep above serpentinite bedrock, and outcrops are common.

Associated species include *Quercus agrifolia* Née, *Quercus durata* Jeps., *Umbellularia californica* (Hook. & Arn.) Nutt., *Festuca microstachys* Nutt., *F. idahoensis* Elmer, *Elymus multisetus* (J.G.Sm.) Burtt-Davy, *Koeleria macrantha* (Ledeb.) Schult., *Triteleia laxa* Benth., *Brodiaea elegans* Hoover, *Sisyrinchium bellum* S.Watson, *Eriogonum luteolum* Greene var. *caninum* (Greene) Reveal, *Eriogonum nudum* Benth., *Leptosiphon androsaceus* Benth., *Eschscholzia californica* Cham., *Chlorogalum pomeridianum* (DC.) Kunth, *Antirrhinum vexillocalyculatum* Kellogg, *Gilia capitata* Sims subsp. *capitata*, *Acmispon brachycarpus* (Benth.) D.D.Sokoloff, *Hemizonia congesta* DC., *Lessingia ramulosa* A.Gray, *Achillea millefolium* L., *Monolopia major* DC., and *Madia exigua* (Sm.) A.Gray. In addition to *S. anomalus* and *Eriogonum luteolum* var. *caninum*, two other rare serpentine endemic species are present in the serpentine grasslands at Mount Burdell Open Space Preserve, *Fritillaria liliacea* Lindl. and *Hesperolinon congestum* (A.Gray) Small.

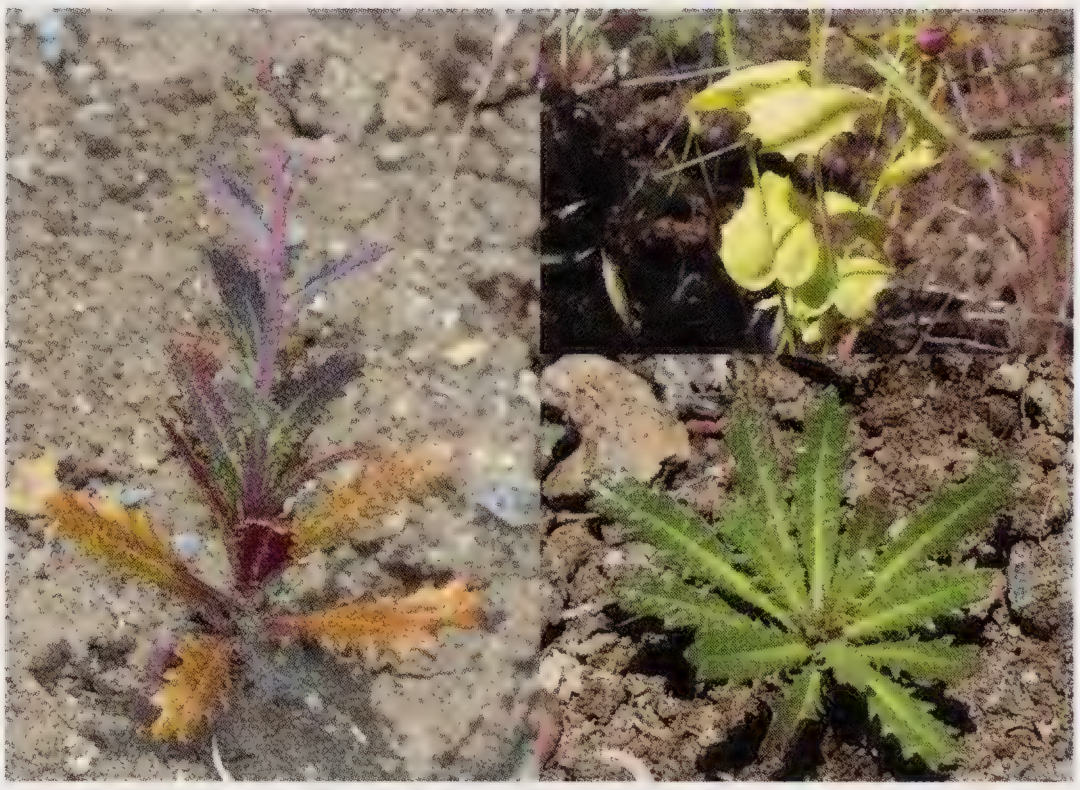

FIG. 3. Leaves of *Streptanthus anomalus*. Lower right: basal rosette. Left: lower and middle cauline leaves. Upper right: upper cauline leaves.

TAXONOMIC CONSIDERATIONS

Because *Streptanthus anomalus* possesses characteristics of both *S. glandulosus* and *S. tortuosus* (Table 1), this poses questions about its relatedness to both species and whether it might have had a hybrid origin. In the most recent phylogenetic analysis of the genus *Streptanthus* and its allies (Cacho et al. 2014), the *S. glandulosus* complex (=*Streptanthus* section *Euclisia*) is part of a clade that is basal to the clade containing the Tortuosus Alliance, which includes *S. tortuous*, *S. diversifolius* S.Watson, *S. farnsworthianus* J.T.Howell, and *S. fenestratus* (Greene) J.T.Howell, all of which have bracted inflorescences. The relative position of these two clades in the phylogenetic tree indicates a substantial divergence time between them, with the

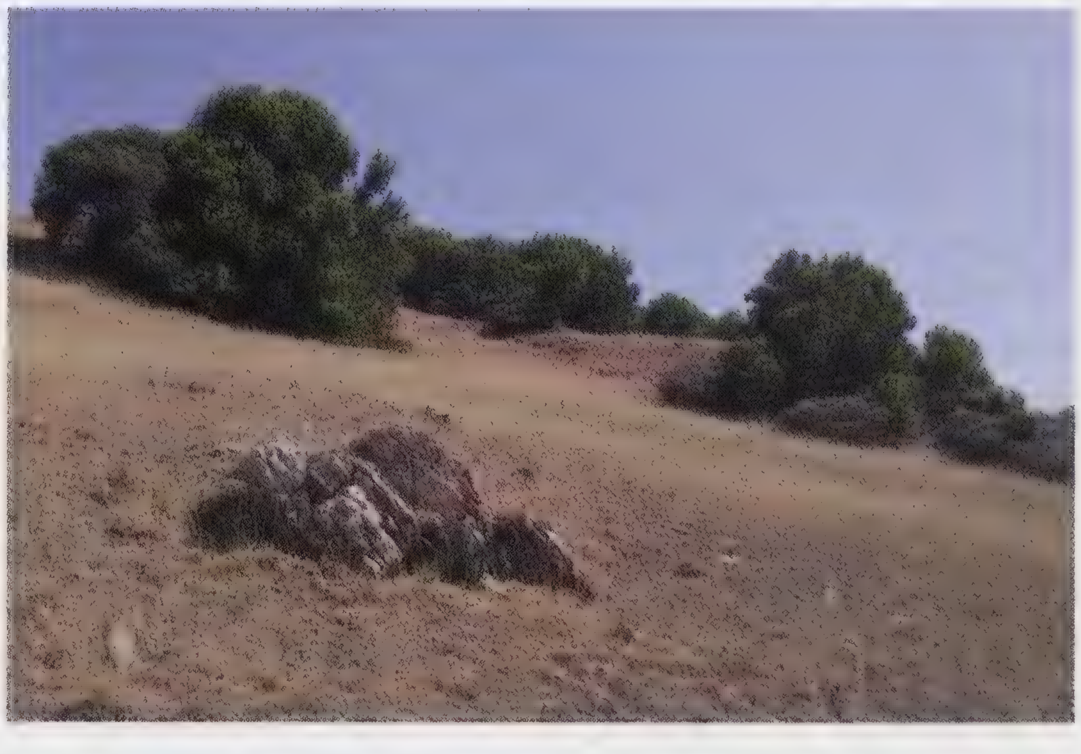

FIG. 4. Habitat for *Streptanthus anomalus* at the ecotone between oak woodland and grassland. The serpentine soils are shallow, with scattered rock outcrops.

TABLE 1. COMPARISON OF SIX CHARACTERS IN *STREPTANTHUS GLANDULOSUS*, *S. ANOMALUS*, AND *S. TORTUOSUS*.

	S. glandulosus	*S. anomalus*	*S. tortuosus*
Pubescence	Proximal stems and leaves bristly-hairy	Proximal stems and leaves bristly-hairy	Glabrous throughout
Basal Rosette	Absent	Present	Present
Basal Leaf Morphology	Oblanceolate, dentate	Oblanceolate, dentate	Spatulate, entire to distally dentate
Distal Leaves	Lanceolate to lance-linear, not bracting proximal flowers	Ovate, bracting proximal 1–2 flowers	Round to oblong-ovate, bracting proximal 1–2 flowers
Flowers	Bilateral, sepals strongly keeled	Bilateral, sepals strongly keeled	Weakly bilateral, sepals not or weakly keeled
Upper Stamens	Filaments connate, anthers sterile	Filaments connate, anthers sterile	Filaments free, anthers fertile

S. glandulosus complex diversifying in the Coast Ranges and the Tortuosus Alliance diversifying primarily in the Sierra Nevada. Because reproductive isolation between *Streptanthus* species is strongly correlated with the divergence time between them (Christie and Strauss 2018), a recent hybrid origin of *S. anomalus* seems highly unlikely.

As noted in the introduction, the floral morphology of *S. anomalus* is consistent with members of *Streptanthus* section *Euclisia*. In contrast, flowers of *S. tortuosus* are less strongly zygomorphic, all stamens are free to the base, and all anthers are fertile. Floral character differences, which may have evolved as prezygotic barriers to hybridization, are also strongly correlated with divergence time (Christie and Strauss 2018). Because *S. anomalus* possesses the floral morphology of *Streptanthus* section *Euclisia,* it is best regarded as a member of that section. The strongly dentate proximal leaves and hispid leaves and stems of (Fig. 3), also shared with *Streptanthus* section *Euclisia*, but not with *S. tortuosus*, also support this relationship.

Streptanthus section *Euclisia* currently consists of between seven and nine subspecies of *S. glandulosus* that differ from one another in perianth color, degree of pubescence, and orientation of the flowers and fruits (Al-Shehbaz 2010, 2012; Mayer and Beseda 2010). All the subspecies have lanceolate to lance-linear cauline leaves, and none have distal leaves that are bracting the proximal flowers of the inflorescence. The distinctly-different bracted inflorescence found in *S. anomalus* (Figs. 1, 2), which is its most anomalous and distinguishing feature, supports its recognition at species rank. Future research of *S. anomalus* should focus on understanding whether its morphology represents convergence or a homoplastic loss in the rest of *Streptanthus* section *Euclisia*.

CONSERVATION STATUS

Streptanthus anomalus is extremely rare and localized, with a combined total of less than 1,500 individuals in both populations. The northern larger population is located on private land within a conservation bank, although it is subject to disturbance by grazing cattle. The southern smaller population is secured within the Mount Burdell Open Space, although it is also subject to disturbance by grazing cattle. In 2015, cattle trampling churned up a substantial portion of the southern population when soils were quite soggy from a prior rain event, and in 2018, we observed that only a few viable siliques remained after cattle grazing had occurred. Grazing is often used as a management tool to reduce the cover of alien grasses and potentially reduce the level of competition with native species. Grazing may increase native species richness on sites with serpentine soils (Safford and Harrison 2001; Harrison et al. 2003, but see Harrison 1999), but it may also have direct adverse effects on native species that offset the benefits of reduced competition (Kimball and Schiffmann 2003). The adverse effects of cattle grazing we observed indicate a need for a more focused grazing prescription in the areas where *S. anomalus* is present.

Applying the NatureServe ranking criteria (Faber-Langendoen et al. 2012), the species would likely warrant global (G) and State (S) ranks of 1 (Critically Imperiled — at very high risk of extinction due to extreme rarity [often 5 or fewer populations], very steep declines, or other factors). We recommend a California Rare Plant Rank of 1B.1 (Rare or Endangered in California and elsewhere, seriously threatened in California) in the California Department of Fish and Wildlife (CDFW) Special Plants list (CDFW 2018) and the California Native Plant Society (CNPS) Inventory of Rare and Endangered Plants (CNPS 2018).

ACKNOWLEDGEMENTS

We thank Vernon Smith for directions to the southern population and for permission to use his close-up photos of the yellow-flowered morph; Dick O'Donnell, Roger Raiche, Ihsan Al-Shehbaz, Dean Taylor, and Nick Jensen for helpful discussions about the taxonomic identity of the Mt. Burdell jewelflower; David Greenberger for comments on proposed names for the species; and, two anonymous reviewers for comments which helped improve the manuscript. Support for the manuscript preparation was provided to R. Preston by ICF.

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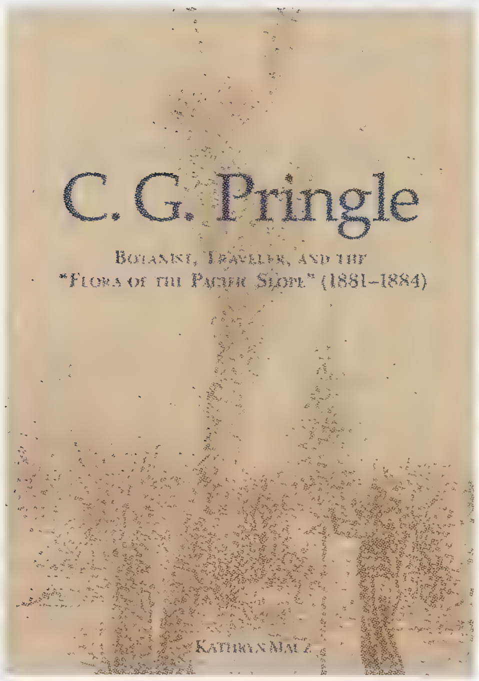
MADROÑO, Vol. 66, No. 1, pp. 30–32, 2019

Review


C. G. Pringle
Botanist, Traveler, and the "Flora of the Pacific Slope" (1881–1884)
Kathryn Mauz

C. G. Pringle: Botanist, Traveler, and the "Flora of the Pacific Slope" (1881–1884) by K. MAUZ. 2018. Memoirs of The New York Botanical Garden, Volume 120, Heritage Series, Number 3, NYBG Press, Bronx, NY. 760 pp. ISBN:978-0-89327-556-3 (hardcover). Price: $129.99.

Today, Cyrus Guernsey Pringle is best known to botany as the premier plant explorer of northern Mexico in the age of the railroad, when travel in the West became exponentially easier than it had been before. Years-long overland discovery expeditions of the early 19th century became season-long or only year-long collecting trips when the transcontinental railroads were complete, enabling much more efficient work. Now, a botanist could work alone and time his trips to coincide with the proper season to locate plants in flower or in fruit, swiftly moving as needed from station to station.

This book tells the story of the first plant explorer to take full advantage of this new opportunity in America. It comprises two main sections: a forensic travelogue of Pringle's early travels during an important phase of American botany and a reference catalogue of the plant collections made on these travels. It covers a short period, only four years, of Pringle's explorations when he was first collecting in the American West and first learning its flora prior to his more than two decades of work in Mexico.

The Mexican work was documented by Davis (1936), relying on Pringle's field books but, unfortunately, Pringle did not maintain a field diary of these earlier efforts. The current volume fills out the record admirably.

Such was the opportunity afforded to Pringle in the early 1880s when he was commissioned by C. S. Sargent, director of the Arnold Arboretum, to collect information on the trees of western forests for the 10th US Census (the resulting Report was published in 1884) and at the same time to collect samples of tree logs for the Jesup Collection of North American Woods, a privately funded effort promoted by the American Museum of Natural History in New York. Brainerd (1911) noted that Pringle's remit also included making general collections for Asa Gray, eminent botanist at Harvard University, and Mauz here notes several other prominent botanists for whom Pringle made collections. As was common in those times when the world was building large herbaria and the West was new, Pringle also supported his own work by selling duplicate sets of each season's collecting. Today, his specimens are found in many important herbaria and continue to inform systematics.

A native and resident of Charlotte, near Burlington, Vermont, Pringle had a successful early career in agriculture and horticulture. Family circumstances interrupted formal study at the University of Vermont, but he was very bright and found an extensive circle of acquaintances in the horticultural world, the University, and the Vermont Department of Agriculture. He ran a successful nursery, was a plant breeder achieving success and a measure of fame with potatoes, wheat, and oats, and was a student of the local flora. In the mid-1870s, he became enamored of plant exploration and collecting, first at the request of botanical correspondents who wanted specimens of some of Vermont's rarer plants. Writing many years later (Pringle 1897), he recalled, "The times yielded me an opportunity and I was ready to grasp it, was fitted by possession of leisure and strength and taste of absorbing passion to follow out the tasks set me. . . . So, I was sent out on quests for these treasures." He rather quickly exhausted local opportunities, especially among the ferns, in Vermont, the St. Lawrence Valley, the Saguenay, and northern Maine. These early parts of his life are quickly covered in Chapters 1 and 2, Introduction and Prelude (1875–1881).

Thus, Pringle was both ready and eager to undertake the western commissions when offered. His four years of trips to the "Pacific Slope" (i.e., west of the Continental Divide) in Arizona, California, Oregon and Washington—and two short side trips to Mexico—form the travelogue portion of Mauz's book (Chapters 3–9). This section supplies the diary that Pringle never wrote. His itineraries are recovered from correspondence, various paper trails such as expense accounts, receipts, and hotel registers and, most importantly, the plant specimens that he carefully collected and labeled. It is fortunate for the historian that Pringle, more than any other early collector, produced labels that went at least somewhat beyond the "less is more" mindset of earlier collectors. Even though the label data still remain sparse, Mauz is able to recapture Pringle's day-to-day movements, thus putting the specimens into far more context than they would otherwise be. With over 2700 collections, there is a wealth of data supporting this account.

Not that Pringle's work, made efficient in comparison to earlier times, was easy. He was healthy and vigorous, but Pringle was over 40 when this work began. The railroads were swift, but travel into the mountains and canyons still required horses and carriages (hired or purchased) and plenty of travel on foot. The collecting itself was strenuous, especially obtaining the sections of logs, heavy and cumbersome to prepare and transport, and the careful collection, pressing, and care of the many specimens of trees, shrubs, and herbs, with multiple duplicates, often in adverse weather conditions. But it is evident that Pringle much enjoyed the work, that he was very knowledgeable about the flora, and that he was, indeed, the right person for the job. The general reader may feel that there are a few too many (if entirely logical) speculations (e.g., he "would have seen" such and such a plant, or "may have arrived at" such and such a place), but Mauz does her best to make the travelogue flow smoothly. Although it would be wonderful to have Pringle's own record and impressions of the particularities of these trips, Mauz's tracing of the itineraries and telling of the plants makes engaging reading.

Interwoven through the travel narrative are accounts, often supported by lengthy quotations from correspondence, of Pringle's interactions with his employers concerning his progress, with other botanists such as Asa Gray at Harvard, George Engelmann in St Louis, and Charles Parry in California, concerning the plants, and with other collectors working in the region. Some of these other workers were rivals. As has happened many times in botanical history, they competed to be the "first to find" a new species. For example, John Lemmon scooped Pringle on *Woodsia cochisensis* Windham in the Santa Catalina mountains of Arizona, causing Pringle some consternation. In the end, however, Pringle himself discovered so many plant species new to science, including on these early trips—e.g. the eponymous *Cheilanthes pringlei* (now *Myriopteris pringlei* (Davenp.) Grusz & Windham), *Poa pringlei* Scribn. ex Vasey, *Agave pringlei* (now *Agave deserti* var. *pringlei* (Baker) W.C.Hodgs. & Reveal), *Pachycereus pringlei* Britton & Rose, and *Arctostaphylos pringlei* Parry—that he saw the rivalries as pointless, but the discoveries as important.

The extensively quoted correspondence also gives us insight into Pringle's personality and character. His modesty, kindness, and earnestness were well known to others during his lifetime and upon his death extensively praised by his Vermont colleague, Middlebury College President Ezra Brainerd (Brainerd 1911). Most readers will be aware of Pringle's reputation as a conscientious objector to service in the Civil War, which is treated briefly in Chapter 1. He was detained in military prison for several months and finally released only on the direct order of President Lincoln. His diary of this experience, first published after his death (Pringle 1913), reveals a man of deeply held beliefs and a serene attitude toward life. Thus, he was able to endure the difficulties of life on the trail and any antagonisms encountered.

However, one is a little surprised to read Engelmann's description of him in a letter to Asa Gray (quoted on p. 110) as "that staid Yankee," with the hint of unimaginative propriety and dull devotion to duty that phrase can imply. One has not previously had the impression of Pringle as "staid" because we in Vermont know of his real enthusiasm (masked by shyness), as witnessed by Vermont botanist W. W. Eggleston's account of their first meeting—both on foot, they passed on the road near Pringle's home without greeting, neither wanting to speak first although both suspected who the other was—followed by a strenuous field trip through Vermont hills and bogs (Eggleston 1912).

One happily confirms that impression of Pringle by learning here of his downright enthusiasm for photography, learned alongside botanist and fern specialist George E. Davenport in these years, and resulting in well composed and well executed photographs of his travels and his plants, about a dozen of which are included in the volume and which add immeasurably to it. These photographs are a remarkable part of the record.

In the end, we see that Pringle was not only the Prince of Collectors, as Gray so famously styled him, but also a good photographer, and, taking into account his contributions to the Report of the 10th US Census (not reproduced by Mauz, but summarized on p. 19), evidently a good observer and keen reporter. That he did not describe species or write extensively about his plants and travels, a fact often remarked, is no mark against him; he was an excellent botanist, and he probably had more fun than most.

Following the narrative are several appendices that are equally as informative as the text itself: lists of the logs collected for the Jesup Collection, a long list of Pringle's plants sorted by locality (county-level and municipal level), a complete catalogue of label data for all of the collections that constituted Pringle's "Flora of the Pacific Slope," and a short list of the specimens collected during his trips that were not part of the "Flora." Last and handiest of all to one reading the travelogue, Appendix E is an historical atlas of Pringle's collecting localities during this period, with an overall map and several regional maps, all of the period. There is hardly anything more one could wish for in this book, but on our very short list would be at least one modern map of Pringle's localities and itineraries, and that this would be inserted up front for easier reference. Perhaps such a map might have replaced the front or back endpaper. Extensive notes (with the referenced text pages listed at the top of each page of notes—a system to be widely recommended) follow, many worth reading stand-alone, especially the short biographies. Numerous references and two indices (to people and place names, and to plants) round out the volume.

Regarding the book itself, the cover is pleasing, with a gold-embossed frond of *Myriopteris pringlei* on the cover (the same image used at chapter headings and gold-embossed title on the spine) and has a well-designed dust jacket. The layout and typography are nicely handled, with long quotes set off in paragraphs slightly narrower than the main text and fully justified (the main text is only left-justified). Printed on coated, archival paper, it is quite hefty, as suits the dignity of its subject.

—ART GILMAN AND DAVID BARRINGTON. The Pringle Herbarium, Jeffords Hall 305, 63 Carrigan Drive, Burlington, VT 05405

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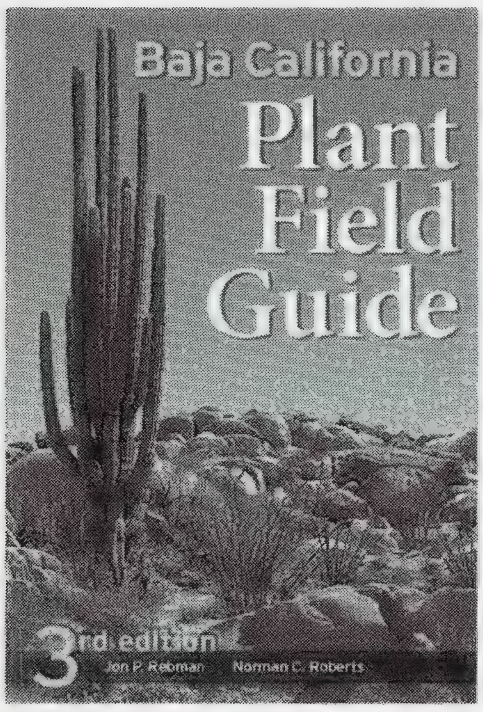
Review



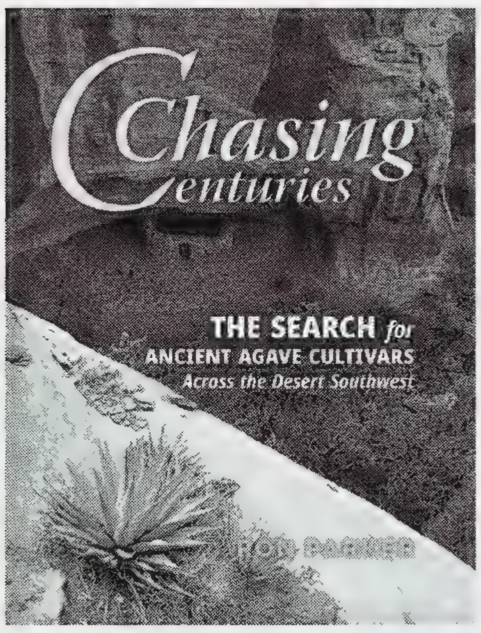
Baja California Plant Field Guide, 3rd Ed. by JON REBMAN AND NORM ROBERTS. 2012. Sunbelt Publications, El Cajon, CA. 480 pp. ISBN (paperback): 9780916251185. Cost $34.95, paperback.

Rebman and Roberts' *Baja California Plant Field Guide* is a seminal work and an absolute necessity for anybody interested in making the great leap over the border, where the California Floristic Province gradually transforms into the landscape of the Sonoran Desert, and later, into a climate and landscape that has more of an affinity with Mainland Mexico (i.e., dry winters and wet, tropical summers) than it does with a climate and landscape resembling anything even remotely Californian. With such a diverse array of habitat types and climate as the Baja Peninsula has, it would be hard to adequately sum up the floristics of the peninsula in a mere 480 pages, yet this field guide does exactly that. I bought my first copy five years ago, and its tattered and worn cover has experienced many a rainstorm and sun-baking since. This guide contains an introduction with a short explanation of the nuances of geology, geography, and climate patterns that dictate the flora of this wonderful landscape, as well as touching on the plate tectonics (i.e., the peninsula's separation from mainland Mexico 6 million years ago) that are at the root of so much of the evolution and diversity present on the peninsula. Like any respectable field guide, plants are organized by family, and the paragraph-long descriptions of each taxon contain some curious and noteworthy information, including ethnobotanical uses, recent phylogenetic developments, descriptions of habitat and distribution, and morphological differences helpful in differentiating one species from those that are closely related to it.

—JOEY SANTORE, Oakland, CA.

Madroño, Vol. 66, No. 1, pp. 34, 2019

Review


Chasing Centuries
THE SEARCH for ANCIENT AGAVE CULTIVARS
Across the Desert Southwest
RON PARKER

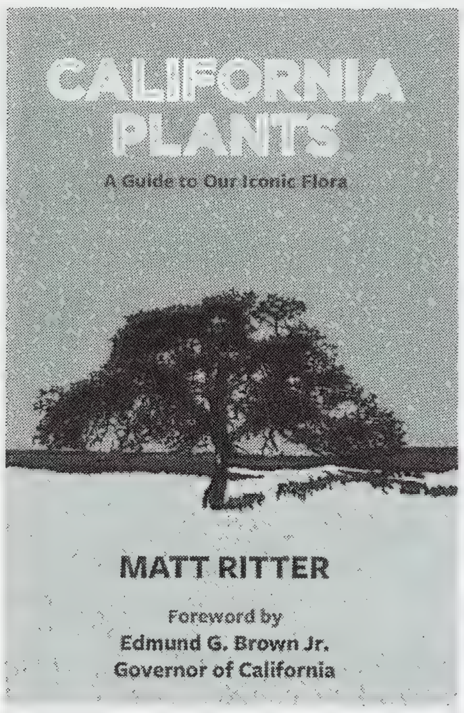
Chasing Centuries: The Search for Ancient Agave Cultivars Across the Desert Southwest. by Ron Parker. 2019. Sunbelt Publications, El Cajon, CA. 176 pp. ISBN (paperback): 194138448X. Cost $26.95 (paperback).

Chasing Centuries was a bit of a surprise, as though I am enthralled by agaves, I am much less enthralled by the archaeological and ethnobotanical aspects of most botany than by the evolution, systematics, and ecological side of the subject. This book, however, gives an excellent introduction into agaves with a quick breakdown of the differences between the two subfamilies and the three types of inflorescence that are useful in identification. And for someone who usually expresses minimal interest in ethnobotany, I was eventually won over by the Parker's very enlightening and fascinating descriptions of tracing the patterns of a culture, people and civilization—a human landscape now so tragically replaced by freeways and strip malls. The author transports the reader through the remnant populations of this genus, which was such an integral part of human survival on an arid landscape. This book was an eye opener for me. It helped me gain a better perspective on retracing the past and the intimate connection between humans and plants that once existed. This relationship between plants and people can still be directly observed through the current distribution of extant populations of *Agave* hybrids and the "grid fields" of stone structures that were once employed to cultivate them, many of which remain on the desert floor to this day. This is an excellent book and should be on the bookshelf of not only those who appreciate agaves but also those who would like to learn how to interpret the present-day landscape in order to get glimpses of the past.

—Joey Santore, Oakland, CA.

MADROÑO, Vol. 66, No. 1, pp. 35, 2019

Review



California Plants: A Guide to Our Iconic Flora. By MATT RITTER. Pacific Street Publishing, San Luis Obispo, CA. 321pp. ISBN: 978-0-9998960. Price $27.50 (paperback).

Matt Ritter's *California Plants: A Guide to Our Iconic Flora* is a marvelous introduction and guide to California's extraordinary flora, well-suited to college students of all levels, to the general botanical enthusiast, and to professional botanists alike. At 9″ × 6″ and 1.6 pounds, the book is easy to carry and enjoyable to open with an alluring, accessible design format. It presents an intelligent overall composition, providing the reader with compelling information. At every stage of presentation—through prose and imagery, facts, description, and nuance—doors are opened for the reader to explore ecology, ethnobotany, botanical history, nomenclature, pollination, and morphology. *California Plants* is beautifully illustrated with over 1,000 high-resolution photographs. The read is a journey worth taking!

The relevance of Dr. Ritter's book is found within the first pages in the forward written by Governor Jerry Brown, a timely narrative in light of Brown's September 2018 California Biodiversity Initiative (California Biodiversity Action Plan 2018), which carefully lays out "A Roadmap for Protecting the State's Natural Heritage," especially California's plant life.

The opening statement of *California Plants*, "California is one of the world's few biodiversity hotspots" prepares the reader for the richness of the seven broad habitat types explored throughout the guide: shrublands, wildflowers and grasslands, forests and woodlands, coastal plants, marshes and wetlands, deserts, and lastly, non-native plants. Many other habitat types might have been explored, for example, serpentine, gabbros and sand hill habitats, montane meadows, or alpine scree fields and the book could have been expanded 2 times over. *California Plants* is oriented toward the more common habitats that we encounter in California and there surely are more that might have been included. And this is not the only book one should read. On Pages 298 and 299 is a list of books and online references for people to explore further and in many different directions.

In the introduction to the treatment of each group, a brief narrative about the variations within vegetation types is included. The shrubland chapter covers species occurring in woody chaparral and coastal scrub communities; the forest and woodland chapter covers species in oak savannah woodlands, montane forests and riparian woodlands; the coastal plant chapter covers dune species and coastal cliff and bluff species; and the wetland chapter covers tidal wetlands and freshwater marshes. The book includes over 300 pages with more than 500 species described and photographed.

Within the chapters, one full page is devoted to each species treatment. Common and widespread species are covered in lieu of rare and isolated species or those with limited range. The purpose of the book is to provide access to knowledge about California plants, not to inform the reader of the rare endemics abundantly scattered across the California landscape. In some cases, genera rather than species are covered, as with manzanita (*Arctostaphylos*).

Wonderful descriptions and brilliant photographs are impressively composed on every page. Each species or genus description includes a common name, a phonetic pronunciation rendition, and the linguistic breakdown of the Latin and Greek botanical names. The morphology of plants is often highlighted along with ethnobotanical and medicinal properties, descriptions of plant associations, and botanical history (e.g., the origins of species names), thus providing a generous element of human botanical history.

As well as being a resource for the botanically inclined enthusiast of the state's flora, *California Plants* is among the important books that educators might introduce to their students for the simple reason that the guide contains the right blend of allure and inspiration to ignite a career in botany, ecology, horticulture, or a related field. Like the ancient pre-Socratic philosopher, Heraclitus, observed "*…all things are born out of fire…*" so it goes, that fires require sparks. There are plenty of sparks in *California Plants* to ignite a fire for those of us fortunate to come across its pages.

—BRETT HALL, Arboretum and Botanic Garden, University of California, Santa Cruz, CA 95064. brett@ucsc.edu

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MADROÑO, Vol. 66, No. 1, p. 36, 2019

2019 GRADUATE STUDENT SYMPOSIUM AT CAL POLY, SAN LUIS OBISPO

Save the Date! The 2019 Annual Banquet & Mixer of the California Botanical Society will be held at the California Polytechnic State University, San Luis Obispo on Saturday, April 6, 2019. The CBS Council is delighted to report that Dr. David Lowry (Professor in the Department of Plant Biology, Michigan State University) will be delivering the evening's presentation entitled "Mechanisms of local adaptations to California's coastal and inland habitats in the yellow monkeyflower." Details regarding the symposium's time and location, registration and payment, and recommendations for lodging will be announced on the CBS website (calbotsoc.org) in December 2018. Field trips will also be offered during the weekend of the symposium.

—SUSAN J. MAZER, President, California Botanical Society, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, 93106, mazer@lifesci.ucsb.edu

MADROÑO, Vol. 66, No. 1, p. 37, 2019

UPCOMING CHANGES IN THE CONSORTIUM OF CALIFORNIA HERBARIA

The Consortium of California Herbaria (CCH) began as a data aggregator for California vascular plant specimen data and that remains its primary purpose to date. From 2003-2017, the CCH grew in size to over 2.2 million specimen records from 36 institutions. In 2018, three new members of the CCH were added and this year four additional herbaria are preparing to join the CCH. This brings the current total members of CCH to around 43.

Responding to requests from participants to display specimen data from all groups of plants and fungi, from all locations (including those outside California), we have developed a new Symbiota portal (CCH2). With the addition of the new CCH2 Symbiota portal, there are now two CCH portals and each has a special purpose (see Table 1).

The original CCH portal (http://ucjeps.berkeley.edu/consortium/) is not being retired. It is being repurposed and is now referred to as CCH1. CCH1 is a specialized portal for presenting highly curated specimen data about the California vascular flora and is tightly linked to Jepson eFlora (http://ucjeps.berkeley.edu/eflora/). It is restricted to vascular plant specimens of native and naturalized taxa from California. This portal will include California specimen records from many sources worldwide. The Index to California Plant Names (ICPN, http://ucjeps.berkeley.edu/db/icpn/) will continue to be developed and will be used for both the Jepson eFlora and CCH1.

The new CCH2 portal (http://cch2.org/portal/) is being developed as a general Symbiota portal, serving all specimen data from all participating CCH members. When complete, it will be worldwide in scope and have a broad taxonomic coverage of land plants, algae, lichens, and fungi. The development of this new portal has been funded by the California Phenology Thematic Collections Network (CAP-TCN). The CAP-TCN is made possible by the National Science Foundation Award (NSF Division of Biological Infrastructure, Award #1802312). This grant is funding the capture of images, label data, and phenological (i.e., flowering time) data from nearly 1 million herbarium specimens. These images and phenological data will increase our understanding of changes in flowering patterns over time, which is valuable to researchers studying climate change in California.

Both portals are currently online and available to the public. However, not all member data in the original CCH1 are present in CCH2. Conversely, new records in CCH2 will not be found in CCH1 until it is completely converted into the new format. Changes and additions to each of these portals are expected to be complete by December 2019.

—JASON A. ALEXANDER, Biodiversity Informatics Manager, University and Jepson Herbaria, University of California, 1001 Valley Life Sciences Bldg, Berkeley, CA 94720.

TABLE 1. DIFFERENCES BETWEEN THE CCH1 AND CCH2 PORTALS.

	CCH1	CCH2
Geographic coverage	California only	Worldwide scope
Taxonomic coverage	Vascular plants only	All specimens in member herbaria
Data source	Worldwide herbaria	Only California herbaria
Taxonomy	Linked to Jepson eFlora	Worldwide taxonomic database
Quality control	Counties corrected, collectors standardized, errors and typos fixed, error reports sent back to each CCH member	Cleaning done by each CCH member, corrected by data owner
Database management	No direct database management (downloaded monthly)	Live databases (real time changes) and snapshot databases (periodic updates)

Volume 66, Number 1, pages 1–38, published 10 June 2019

SUBSCRIPTIONS-MEMBERSHIP

The California Botanical Society has several annual membership categories: Regular $50, family $55, emeritus $35, student $20, postdoc $35 and life $1,000. Members of the Society receive Madroño free, in print and online, and can opt not to receive Madroño in print. Institutional subscriptions to Madroño are $85 per year. Membership and institutional subscriptions are based on the volume year of Madroño, which follows the calendar year. Applications for membership/institutional subscriptions and renewals may be made online or by sending the membership form (also available online) to the Membership Chair. Requests for changes of address, and Madroño delivery inquiries should be sent to the Membership Chair. Orders for back issues of Madroño may also be made online at calbotsoc.org or by sending the order form (available online) to the Corresponding Secretary. Price and mailing cost inquiries for back issues of Madroño should be sent to the Corresponding Secretary.

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Manuscripts may be submitted in English or Spanish. English-language manuscripts dealing with taxa or topics of Latin America and Spanish-language manuscripts must have a Spanish Resumen and an English Abstract.

For all articles and short items (NOTES, NOTEWORTHY COLLECTIONS, POINTS OF VIEW, etc.), follow the format used in recent issues for the type of item submitted. Detailed information for contributors, including instructions for manuscript preparation, is available at the California Botanical Society website, http://calbotsoc.org; follow the link to Madroño.

All California Botanical Society members current in the volume year that their contributions are published are allowed five free pages per volume year. Additional pages will be charged at the rate of $40 per page. Joint authors may apply all or a portion of their respective five-page allotments to a jointly-published article. Partial pages will be charged as full. The purpose of this fee is not to pay directly for the costs of publishing any particular paper, but rather to allow the Society to continue publishing Madroño on a reasonable schedule, with equity among all members for access to its pages. Printer's fees for color plates and other complex matter (including illustrations, charts, maps, photographs) will be charged at cost. Author's changes after typesetting @ $4.50 per line will be charged to authors. Page charges are important in maintaining Madroño as a viable publication, and timely payment of charges is appreciated.

At the time of submission, authors must provide information describing the extent to which data in the manuscript have been used in other papers that are published, in press, submitted, or soon to be submitted elsewhere.

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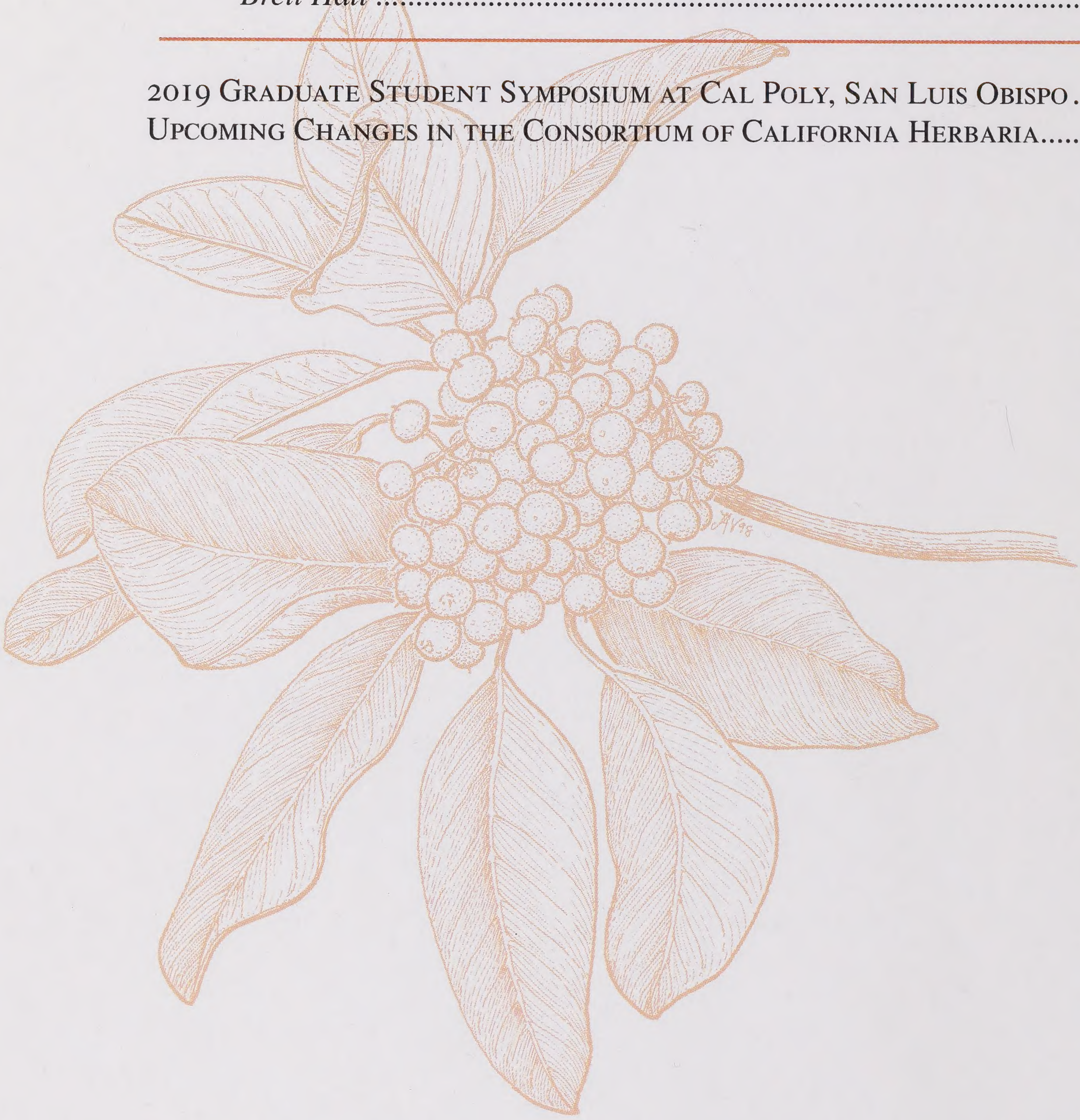

Volume 66 of Madroño is dedicated to Jessica Mae Orozco